Response to the 1st SHINE TAC Meeting Report

The SHINE TAC meeting was held as an online meeting, focused on topics listed in the agenda below, and concluded with a closeout with SHINE management that provided initial observations, findings, and recommendations.

The TAC thanks the SHINE staff for their contributions and the open discussions that made this an enjoyable and useful meeting.

SHINE TAC Members

Name	**Affiliation**	**Attending**	**Comments**
Christoph Bostedt	PSI	No	
Gang Chen	IHEP	Yes	
Mario Ferianis	ELETTRA	No	
Jan Grünert	European XFEL	Yes	
Ingmar Hartl	DESY	Yes	
Qingyu Kong	SOLEIL	Yes	
Yongbin Leng	UST China	Yes	
Aldo Mozzanica	PSI	Yes	
Changyong Song	POSTECH	Yes	
Thomas Tschentscher	European XFEL	Yes	Chair
Makina Yabashi	Spring-8/RIKEN	Yes	
Marco Zangrando	ELETTRA	Yes	

Agenda (hrs in Shanghai/Japan Korean/European time) **April 17 (Wednesday)**

15:00/16:00/09:00	SHINE management with TAC	Closed-session
15:30/16:30/9:30	SHINE Status & Introduction Areas	Talk (Zhi Liu)
16:30/17:30/10:30	TAC discussions	Closed-session
17:15/18:15/11:15	Break	
17:30/18:30/11:30	Beamline design, stability, particle- free environment	Talk (Chaofan Xue Fang Liu)

18:30/19:30/12:30	TAC discussions	Closed-session

April 18 (Thursday)

15:00/16:00/09:00	Systems enabling FEL Experiments	Talk (Yong Wang, Jiaming Jiang)
16:00/17:00/10:00	TAC discussions	Closed-session
17:00/18:00/11:00	Close-out with SHINE Management	Closed-session

General part, charge questions and TAC responses

0. General part and SHINE overview

Findings: The meeting was started by a welcome and a brief introduction to the SHINE project by Zhentang Zhao and Zhi Liu. It was clarified that the charge of the TAC committee is complimentary to the already operating machine advisory committee. The scope of the TAC includes the generation of the x-ray beams, however the interface of scope between the MAC and the TAC seems not to be fully clarified. A scientific advisory committee is planned to be established once the science user program will commence. Upon being asked, the SHINE management was described and it was clarified that it includes staff from three organizations in charge of building SHINE, namely ShanghaiTech University (STU), Shanghai Advances Research Institute (SARI) and Shanghai Institute of Optics and Fine Mechanics (SIOM). The three institutions share responsibilities as follows: SARI – Accelerator and Undulators, SIOM – High-power lasers and endstations with high-power lasers, STU – Civil utilities, buildings, shafts, experimental stations. The owner of SHINE is STU. The SHINE management team is fairly large, including senior staff from the three institutes, project directors and deputy directors, 6 chief engineers, and work package leaders. A written description of the management and responsibilities of the various persons will be provided to the TAC. It was pointed out that the TAC report shall address an even wider range of persons, responsible for constructing SHINE or parts thereof. Zhi Liu then provided an overview of the SHINE project and its status. Most importantly the project scope had recently been reduced to FEL-I and FEL-II, the respective beamlines, and six science instruments (FEL-I: HSS, CDS, SEL, FEL-II: AMO, SES, SSS), some of which have several end-stations. These science instruments will populate two experimental halls. The full design plans for 3 FEL beamlines with the parameters FEL-I: 3-15keV, FEL-II: 400eV -3keV, FEL-III: 10-25 keV. A 100 PW laser is planned to complement the SEL instrument. With respect to the civil construction and building infrastructure he explained that not all building and areas are yet complete. He further showed the most important milestones for the project, which are

- to generate first FEL beam in March 2026 (at an electron energy of 3 GeV, in the soft x-ray regime using FEL-II),
- to carry out a first ‘User’ experiment in summer 2026,
- to generate FEL beam in spring 2027 (at an electron energy of 6 GeV, in the hard

x- ray regime using FEL-I),

- and to complete SHINE within the presented scope by the end of 2027.

Being a high repetition accelerator the scheme to increase the repetition rate was presented. First FEL light and first experiments shall be done using 10 Hz pulse delivery. Within ten months the repetition rate shall be increased to 100 kHz and reach 1 MHz by end of 2027. The x-ray beam power in the beamlines is defined to be maximum 20W corresponding to a pulse energy of 2mJ operating at a maximum 10kHz. If the beam power could exceed this value, measures to limit the beam power will be engaged. The presentation did indicate laser- and self-seeding for FEL-II and FEL-I, resp., however it was outlined that these techniques are not planned for in the project in the near term.

Observations and comments (bulleted list for better separation of topics)**:**

- The TAC considers the time line to reach the high-level milestones described above as extremely ambitious. It will be necessary to define critical milestones and the timeline leading up to them carefully, as well as to define a prioritization amongst the many systems to be completed. The TAC notes that the time line to increase the repetition rate from 10 Hz to 100 kHz is very ambitious and much shorter than what for example had been realized for LCLS-II. SHINE provided a detailed milestone list during the meeting. For the next meeting it would be good to show in the overview section how these milestones have been reached or where milestones have slipped.
- We were presented with start-up parameters for FEL-II indicating different electron energies (3 vs. 3,6 and 6 vs. 7,2 GeV). The TAC points out that the project requires well-defined target parameters, in particular since the timeline is so demanding.
- The installation and commissioning planning and procedures are unclear. We would like to see more here at the next meeting. Consider not only installation, but commissioning without and with beam, at the same time considering beam sharing of different trades. Consider pre-testing sub-systems and the interplay of different sub-systems. To be ready to perform a first user experiment, commissioning should also include testing the pump laser, synchronizing the laser and X-ray beams, setting time zero, optimizing the jitter, and verifying timing tools.

Xuesong& Jiahua Chen:

Installation:

We started installation in June 2025 and have prepared a detailed daily installation schedule, covering equipment assembly, motion measurement, calibration and alignment, vibration measurement, optical measurement, vacuum acquisition, personal/equipment safety interlocks, and control debugging, from equipment arrival to beamline vacuum penetration.

The biggest challenge in commissioning likely the chain of small apertures and orifices upstream of the M1 mirror, especially the differential pumping orifices and tube sin the gas attenuator. To guarantee that the photon beam can pass through these devices smoothly during the commissioning, high precision alignment is essential. In addition, we plan to use visible alignment laser to pass through these devices after installation to verify the installation accuracy and ensure collinearity.

There are two DAQ computer rooms located in Shaft 4 and 5, respectively. The DAQ computer room in Shaft 4 was already completed in November 2024, while the DAQ computer room in Shaft 5 is scheduled for completion in July 2025.

The network infrastructure in Shaft 4 DAQ computer room was already completed in June 2025, and the DAQ servers plus online fast storage will be ready before November 2025.

For Shaft 5, the network infrastructure is planned to be completed in February 2026, and the DAQ servers and online fast storage are planned to be completed before July 2026.

Commissioning：

The commissioning will be divided into different stages. The Stage I will begin in spring 2026. The electron energy in the Stage I is 3GeV. The main goal of this stage is to guarantee that the photon beam arrives at the AMO and SES experimental stations in FEL-II beamline. In this stage, only the pink beam will be delivered; commissioning of the monochromatic (mono) beam will follow in subsequent stages. Accordingly, the plane grating will be not used in Stage I. Instead, only the ECM will be used to focus the pink beam at the exit slit in the vertical plane to ensure that the object distance of the SES vertical KB mirror matches that of mono beam configuration. The commissioning priority of AMO experimental station is higher than that of SES experimental station because the optical path is more concise for the AMO experimental station. The photon energy chosen for the commissioning is 200eV in the Stage I and we expect to obtain a well-formed spot at the endstation without stringent focusing, given tight scheduling constraints . The commissioning of the focus in the subsequent stages will be achieved using a focal imager in combination with a wavefront sensor. The biggest challenge in the Stage I may be guiding the photon beam can smoothly to the M1 mirror after it passes through a series of differential orifices and differential tubes in the gas attenuator. Success will largely depend on the alignment accuracy and the accelerator’s steering capability ,since the beamline has no beam-steering capability upstream of M1 mirror.

In the first stage, the FEL-II beamline commissioning and the FEL-I beamline installation will be alternate. The arrangement will be 7 days commissioning / 7 days installation. The FEL-II beamline commissioning is planned for completion in July 2027. The FEL-I beamline commissioning will be started in April 2027 and finished in November 2027. A day-by-day preliminary commissioning plan is provided below.

T0+1: Beam arrives at the frontend.

T0+2: Beam arrives at the AMO endstation.

T0+3: Beam arrives at M3a for mono branch with pink beam.

T0+4: Beam arrives at SES endstation.

T0+8: Focus beam at AMO endstation.

T0+12: Focus beam at SES endstation.

T0+24: AMO endstation commissioning.

T0+36: SES endstation commissioning.

- We did not hear about the integration of accelerator and photon system activities. Once the beamline work and experiments start, there will have to be a lot of collaborative work. Consider e.g. regular joint meetings of accelerator and photon system experts.(Please refer to the answer to R1-4)

Recommendations:

R1-1: Provide talks and relevant documents sufficiently early in order TAC members can have a look at them. At least 3 full days prior to the meeting. This material should present the actual facility/system status and be in a near-final form, last minutes changes are possible and the ‘final’ material should be made available to the TAC latest at the meeting. When showing time charts, it would be helpful if you could add FTE needs and availabilities in order to be able to judge the full effort and criticality of the chart. Documents or parts of documents considered as background information should be marked as such, and will not be part of the advises of the respective meeting.

R1-2: Establish a data repository where up-to-date agenda, talks, relevant documents and background material can be accessed and downloaded by TAC. In addition, a .zip file of all documents will ease downloads.

R1-3: The dates for the next TAC meetings should be identified and confirmed with high priority, ideally for the next about 18 months. A sequence of one online and one in-person meeting per year is considered realistic and feasible.

R1-4: The TAC is concerned that the timeline for project completion is very ambitious and unlikely to be followed without delays. This is the case for the steep progress from first light to project completion in 2026 and 2027. The TAC therefore recommends to the SHINE management to seriously analyze the most important project targets and milestones, and to potentially reduce the targets where possible. This would be a careful measure to manage expectations to the project, both internally and externally.

Jie Wang:

Response: We appreciate the TAC committee's feedback.

1，Targets for 2027:

The tables below outline the technical specifications that Beamlines FEL-I and FEL-II must achieve by the end of 2027. A government-appointed panel of beamline/experimental station experts and scientists will conduct testing and acceptance. Full compliance is required to mark the construction completion of 2 beamlines and 5 endstations.

FEL-I	photon energy range: 3.0-13.0keV energy resolution（ΔE/E）: 2×10^{-4} @8.9keV transmission ratio for a single pulse: 15%@7keV focus dimension: 15μm(FWHM）
FEL-II	photon energy range: 0.35-2.0keV energy resolution（ΔE/E）: 1×10^{-4}@867eV transmission ratio for a single pulse：15%@1keV (pink beam) focus dimension: 20×12μm(FWHM）

image resolution of CDS	10nm@>5×10^{13}photons/μm^2@ 5keV
focus size of CDS	≤300nm
spectral resolution of HSS spectrometer	4×10^{-5}
ion momentum resolution of AMO	≤5%

spatial resolution of SES	≤500nm
temporal resolution of SES	≤80fs
spectral resolution of SSS spectrometer	100meV@1000eV

2，The commissioning of the SHINE beamlines and endstations will be an unprecedented process for us. While unforeseen issues may introduce uncertainty, our plan is grounded in the following facts.:

1) *Technical considerations for FEL-II beamline commissioning*: FEL-II beamline design prioritizes requirements of the initial commissioning. Generally, all mirrors and gratings are equipped with fine multi-dimensional adjustments compatible to ultra-high-vacuum. The movement precision and range account for X-ray beam tuning needs. X-ray imagers are installed downstream of each mirror and grating to observe transmitted and/or reflected light. More imagers are placed after beam-confining components (e.g., small-size tubes for vacuum differential, collimators, slits etc.) to monitor potential beam-interception. An imager is also installed between the FEL-II undulator and the beamline photon shutter to monitor the light source at the very beginning of the beamline commissioning. Based on our tests, the imager shows sensitivity to soft X-ray pulse energies at the microjoules level, suitable for low-intensity beams during the initial commissioning.

Stability of FEL-II undulator light source and beamline optics: discussions with undulator engineers indicate that an angular drift of the undulator lasing ≤ 30 μrad exists. The acceptance angle of the FEL-II beamline, limited primarily by the KB mirrors located near the experiment endstations, is about 42 μrad, providing margin for the source instability.

The pointing instability requirement for beamline optics is less than 0.1 μrad. Our laboratory tests of the FEL-II M1 mirror demonstrated a pointing fluctuation of ~0.07 μrad. Vibration damping measures will be implemented in the tunnel to meet stability targets (details refer to our TAC reports).

Lasing characteristics of FEL-II undulators: a dedicated accelerator-side diagnostics system will measure and analyze undulator lasing parameters during initial commissioning to guide further beamline development.

FEL-II beamline alignment network: the beamline alignment network is integrated with the accelerator (including the undulators) alignment network. By extending each network by ~ 100 m into the other, , the 0.5 mm installation accuracy of beamline components will be achieved within the tunnel. In addition, the imager between the undulator and the beamline photon shutter is located in the overlapping zone of two alignment networks, and may act as a reference checkpoint.

2) *Commissioning goals and schedule*: the plan divides the FEL-II commissioning into two phases. Phase I starts from the first lasing (March 31, 2026 anticipated) and concludes at the end of September 2026 (~6 months), and Phase II from March 2027 to June 2027. The objective of Phase I sets achievement of technical specifications of FEL-II beamline and experimental stations at a level of low average lasing power. Accordingly, Phase II aims to achieve all specifications of FEL-II beamline and endstations at full average power the undulators emit.

We understand that the first 3 months of Phase I is our key period for the commissioning. The strategy is to tune a 200 eV pink beam transmitted to the end of FEL-II beamline as soon as possible. The main branch of FEL-II beamline, consisting of mirrors M1, M2a and AMO-KB, will play a critical role in day-one commissioning. A commissioning list including GMD/HAMP calibration, preliminary AMO-KB focusing, time-of-arrival diagnostics, and experimental station setup, etc. will be prioritized according to the experimental prerequisites of AMO-COLTRIMS and SES-TAP.

Pre-commissioning preparations: the pump laser system for FEL-II experimental endstations will complete its commissioning by October 2025. Experimental stations will test equipment/software and conduct experiments using the pump laser system, ensuring that endstations are ready before the FEL-II beamline starts.

3) *Organization*: we are establishing an accelerator-beamline commissioning coordination team, with the help of TAC members and other international expertise.

R1-5: Prepare parameter tables for first beam and experiments, and as well how these parameters shall evolve in time until end of 2027. Ensure internally that all parties know these parameters and work towards them. Present these tables to the TAC at its next meeting.

Huaidong Jiang:

A: Day-1 for the CDS Instrument will be focused on the static high throughput imaging of metallic nanoparticles. To ensure all the sub-systems work well and find out the potential issues & unworked parts, day-1 experiments will try both the micron scale and hundred nano-meter scale foci. To pave a better way for the later pilot experiments and user operations, aerosol injector and fixed target sample delivery methods will be employed.

The primary requirements are the pulse energy and beam stability (pointing and transverse stability)

Time	March ~ June 2027	December 2027

Photon Energy	5 keV	3~13 keV
Average Pulse Energy	≥ 100 μJ (Source Point)	≥ 100 μJ (Source Point)
Beam Stability (at source point, transverse stability)	10%	≤ 10%
Repetition Rate	≤ 1kHz	≤ 2 kHz
Bandwidth	≤ 0.1%	≤ 0.1%
Pulse Length	≤ 100 fs	≤ 100 fs
Arrival Time Jitter	≤ 30 fs	≤ 30 fs
Focusing Capability	1.0 μm 300 nm	1.0 μm 300 nm
Sample Environment	High Vacuum: 10^{-4} to 10^{-7} mbar	High Vacuum: 10^{-4} to 10^{-7} mbar; Atmosphere Helium: 100-600 mbar
Sample Delivery	Aerosol Injector (with Electrospray) Fixed Target (Lower Repe. Rate)	Aerosol Injector GDVN Fixed Target
Detectors	Jungfrau 4M (Repe. Rate: 2.2 kHz Max.)	Jungfrau 4M
Pump Lasers	N/A for first days	1 KHz

Kaiyu Zhang:

Time		March ~ June 2027	December 2027
XFEL beam	operation energy	ca. 7keV	3~13 keV

parameters	Pulse energy @8GeV/100pC	0.2mJ @7keV	0.2mJ @7keV
	Repetition rate	1kHz	1kHz
	Monochromator Energy resolution	Si(111): 2E-4 @3-15keV Si(311): 5E-5 @5.6-15keV	Si(111): 2E-4 @3-15keV Si(311): 5E-5 @5.6-15keV
	Focal spot size at sample (H×V, FWHM)	200μm x 5μm	200μm x 5μm
	Pulse arrival time	≤15fs（RMS）	≤15fs（RMS）
	Pulse length	≤20fs（RMS）	≤20fs（RMS）
Pump laser parameters	Wavelength range	400/266 nm	400/266 nm
	Focal spot size	500 × 500 μm2	500 × 500 μm2
	Pulse energy density	≥ 50 mJ/cm2	≥ 50 mJ/cm2
	Pulse length (FWHM)	≤ 35 fs @800 nm	≤ 35 fs @800 nm
	Repetition rate	1 kHz	1 kHz
	Delay range	20 fs –5 ns	20 fs –5 ns
	Syn. Accuracy	≤ 50 fs	≤ 50 fs
Spectrometer	Crystal analyzer	Si（531）、Ge（620）	Si（531）、Ge（620）
	Bragg angle	73.09°	73.09°
	Solid angle	≥ 35 msr	≥ 35 msr
	Energy resolution	≤ 0.5 eV	≤ 0.5 eV

Xincheng WANG:

The parameter evolve table from my opinion:

	March. 2026	Sep.2026	Jan. 2027	Dec. 2027
Photon energy (eV)	100,200	100-400	100-1000	100-1000
Pulse energy (μJ)	10	10	50	100
Rep. rate (Hz)	10	1 000	10 000	100 000
Band width (%)	1	0.5	0.3	0.3
Pulse width	~200 fs	≤100 fs	≤100 fs	≤50 fs
Laser jitter	/	/	≤50 fs	≤30 fs
beam stability	/	<20%	<20%	<20%

Meixiao Wang:
The requirement of the optical parameters of SES endstation are listed below：

	March. 2026	Sep.2026	Jan. 2027	Dec. 2027
Photon energy (eV)	100,200	100-400	100-1000	100-1000
Pulse energy (μJ)	10	10	10	10
Rep. rate (Hz)	10	1k	10k	100k
Band width (%)	1	0.5	0.3	0.3
Pulse width	~200 fs	≤100 fs	≤100 fs	≤50 fs
Laser jitter	/	/	≤50 fs	≤30 fs
beam stability	/	<20%	<20%	<20%

Xuerong Liu:
The optical parameter requirements for the SSS endstation are listed below：

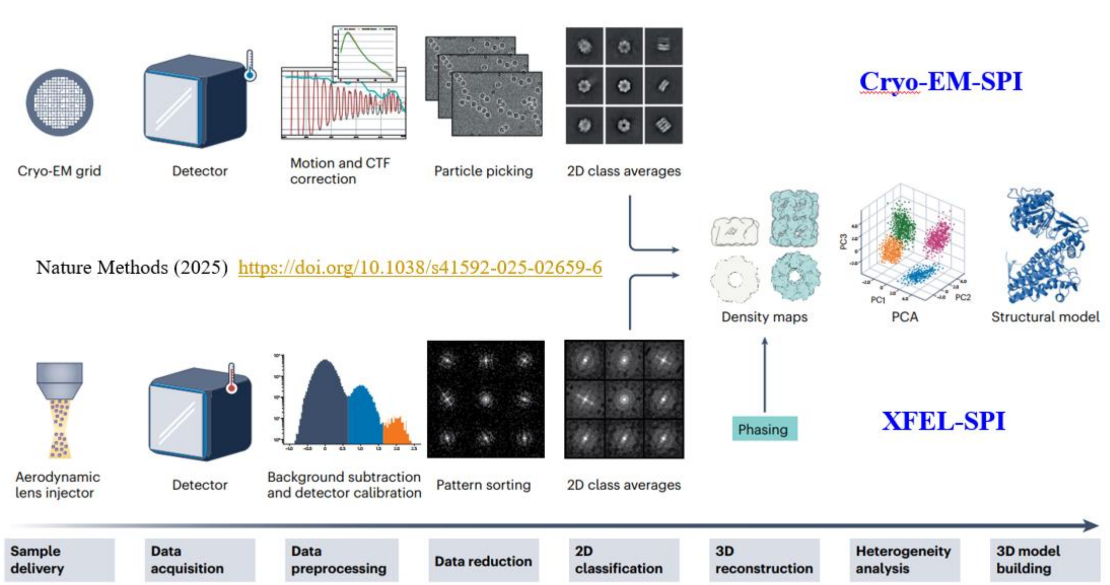
	Sep.2026	Jan. 2027	Dec. 2027
Photon energy (eV)	930±15	400-1700	400-1700
Pulse energy (μJ)	25	25	25
Rep. rate (Hz)	10k	10k	100k

Monochromized Band width (%)	0.005	0.005	0.003
Pulse width	≤100 fs	≤100 fs	≤100 fs
Laser jitter	/	≤50 fs	≤30 fs
beam stability	<1%	<1%	<1%

R1-6: We would like to understand better the strategy for first and early science. Although the instruments and general science cases have been introduced, the TAC would like to understand what are the priorities for machine operation, beamline performance, laser commissioning for the early science program.:

The CDS instrument is designed for capturing ultrafast dynamics and phenomena with the ultrafast X-ray imaging, scattering, and crystallography with high spatiotemporal resolution. The first and early science will focus on the static high-throughput imaging of biological targets, such as viruses (40-100 nm diameter in size). The final results will integrate the XFEL Single Particle Imaging (XFEL-SPI) with Cryo-EM SPI . The second part of the pilot experiments will be focused on IR-pump-induced melting of metallic nanocrystals (i.e. thermal melting time-resolved-SPI over ps-ns timescales.) We'll then extend these studies to metallic core–shell structures with pilot collaborators.

Kaiyu Zhang:



Combination of XFEL and Cryo-EM Single Particle Imaging (SPI)

The initial phase of HSS science will primarily investigate the evolution of chemical bonds and ultra-fast kinetics in the photo-excited state. Specific research topics encompass photo-induced solution isomerization, structural reorganization of the chlorophyll systems, and hydrogenase reactions. Consequently, the design of the early science phase must prioritize the optimization of the pump-probe time scale (fs-ps) and the selection of element absorption edges. Moreover, due to the involvement of significant solvation and dynamic reorganization of the system in solution, the program also requires appropriate matching of the liquid sample environment and solution scattering testing equipment.

The highest priority is the realization of ultra-fast x-ray emission spectroscopy experiments based on our spectrometer with liquid jet. The liquid sample environment will be configured in concert with the spectrometer. We will concentrate on the spatial and temporal overlap of the pump laser and XFEL on the liquid flow or sheet. Subsequently, the on/off spectra data will be collected and analyzed. Upon completion of the demonstration experiment, we will initially increase the repetition rate to 10kHz and systematically explore additional beamline and pump-laser parameters.

Xincheng Wang:

For AMO end-station, the commissioning strategy is to proceed step by step, (i) checking the ion TOF measurement, (ii) validating the electron energy measurement with simple eTOF and inert gas samples, (iii) switching to Coltrims for a coincidence measurement of molecules, and (iv) pump and probe scheme will be commissioned.

For the first step (ion and electron TOF), we would like to have better focusing with higher pulse energy (100 μJ) to generate non-linear effects and it can work with lower repetition rate (10 Hz). With Coltrims and pump-probe commissioning, we require a high repetition rate (10-100 kHz) with reasonable pulse energy (50 μJ) and jitter (<50 fs) between the optical laser and the FEL

Meixiao Wang:

SES is a photoelectron spectroscopy endstation with two spectrometers: a time resolved ARPES station with a hemispherical analyzer, and a dual-mode K-PEEM station that can support both real space and momentum space microscopy. For both spectrometers, high repetition rates and moderate to low power single pulse energy are required to achieve a higher efficiency/statistics data collection while maintain high energy resolution (e.g. to avoid spatial charge effect).

At the early stage, with the repetition rate of ~10Hz, which is too low for proposed research work (the ideal regime is ≥ 100kHz), we will use the FEL beam for basic diagnostics and set up an ultrafast HHG laser source to test the endstation and perform pump-probe experiments. Once the repetition rate reaches 10k Hz, we will begin demonstration experiments to test the multi-color pump-probe experiments, and complete the optimization of instruments across the full photon energy range.

Xuerong Liu:

SSS is a time-resolved resonant inelastic X-ray scattering (tr-RIXS) spectroscopy endstation. Equipped with a grating to reduce pulse stretching caused by monochromatization, the tr-RIXS spectrometer at SSS can achieve high energy resolution (e.g., 50 meV @ 930 eV) and time resolution (e.g., < 300 fs). In the early stage during commissioning, a lower repetition rate is expected, thus we will first focus on excitation phenomena with relatively larger scattering cross-sections, i.e. the spin- and orbital-excitations in parent cuprate superconductor compound La_2CuO_4 at Cu L_3-edge. With laser perturbation, we will address the impact of strong electron correlation on the spin- and orbital-dynamics when the system is driven away from equilibrium with electron repopulation.

R1-7: Given the tight time line until project completion, the large amount of new systems, the importance that these systems function in away allowing the commissioning of SHINE, it might be of help to invite experts from other FEL facilities, bringing experience in specific areas or methods, to support the commissioning of SHINE.

1. Beamline Design, Stability, and Particle Free Environment

This session will provide a comprehensive overview of the beamline design, highlighting key aspects such as optical layout, metrology approaches, vibration measuring and mitigation strategies, and particle-free environment control. It will also outline the general installation and commissioning concepts. Expert advice is sought on how to refine and integrate these subsystems to ensure long-term beam stability and operational reliability.

CHARGE question*: Provide advice on beamline and optical system design, including strategies for stability (e.g., vibration control and X-ray Optics metrology), contamination control, and the creation of a particle-free environment. Comment on the installation and alignment approaches, and recommend procedures or methodologies for commissioning to support long-term performance and reliability.*

Findings: Chaofan Xue presented first the FEL-II Beamline optical design as well as criteria regarding optics quality and parameters, and as well the optical metrology capabilities, including description of lab facilities and instrumentation, which were listed and detailed.

FEL-II is located in tunnel T23 and the beam transport in T34. The FEL-II end-stations AMO, SSS, and SES are located in experimental hall 4. Fang Liu then explained the vibration issue and concepts how to reduce their impact. He presented target values for the stability of the optical elements. Active damping (0-40 Hz) using piezos (not pneumatic) provides better short-term stability but more long-term drifts which could lead to a 2 urad fluctuation.

Passive rubber pads reduce vibrations above 30 Hz. The beam position signal of the XGMDs is considered to serve as a feedback for beam pointing. The online feedback system will serve for frequencies lower than 5 Hz.

Response to the Charge questions:

• Overall the FEL-II beamline and optical system design appears to be sound and making use of the experiences made at other FELs. The sheer number of optical, diagnostics and vacuum items to be integrated into a single beamline is impressive. The concept to spread the beam between the three end-stations, as well as to prepare specific beam properties seems to fit the requirements. One exception maybe that the requirement for monochromaticity by SSS and SES, in particular for the first experiments is a lot smaller than the commissioning parameter for the monochromator foreseen. Here, one could possibly reduce effort and achieve success in a simpler way.

• The vibration issue is for SHINE of particular relevance, due to the environmental noise. The measures to passively and actively damp these vibrations appear to be adequate. The active damping methods could produce complicated long-time drift of the optics. In principle, this complication could be mitigated by introducing a feedback loop with XBPM for every optics, but careful design and studies, as well as preparation of multiple options, should be needed. As well the monitoring of environmental parameters has been considered, and the data of all environmental sensors will be fed into the control system, in order to be available with the experiment data. Temperature and humidity control will be installed.

• Contamination control, and the creation of a particle-free environment are taken seriously to establish particle-free assembly conditions for the beamline elements, in order to avoid future damage of optics and wavefront degradation of the transported beams. Consider ensuring that the vacuum specifications contain not only limits on particle contamination but also define required base pressures and maximum level of hydrocarbon content (ensured by rest gas analysis measurements) to protect optics.

- The installation and alignment procedures are not clear in all aspects (see comments above). This topic should be re-addressed at the next meeting. The installation schedule was shown and looks very ambitious. The TAC had no means to judge on the feasibility of this schedule. However, it would be useful to consider separate commissioning steps and goals without and with X-ray beam. We learned that the final metrology laboratory becomes available now and metrology equipment from the preliminary laboratory at STU will be transferred and re-commissioned. The respective new cleanroom in the shaft building is operational and commissioned. The respective delays need to be considered in the installation plan. With respect to commissioning with beam the aspect of increasing repetition rate and beam power should be specially considered: what is feasible at low rate/power, how will methods and problems change when increasing rate/power?
- With respect to procedures or methodologies for commissioning that will enable long-term performance and reliability we want to point to two specific aspects. When inserting and retracting the offset and KB mirrors the repeatability of these motions will be critical for operation. Data shown are impressive, but the methods so far seem to exclusively rely on encoders. It might be careful to consider as well x-ray beam-based monitors to ensure repeatability. For the correct alignment of the mirrors and KB-optics, beam spot diagnostics in the end-stations will be needed.

Wavefront sensing has been mentioned and will be a crucial device to align and optimize the KB mirror systems. For the experiment areas, diagnostics for the laser beam is important and a device to measure x-ray/optical overlap and delay is required.

Recommendations:

R1-8: Create a combined commissioning schedule reflecting accelerator and photon beamline commissioning leading towards FEL first lasing and consider creating a joint commissioning team of accelerator and photon-side experts. Formulate the alignment procedure for the beamlines and identify all required diagnostics, and ensure they are available. Consider adding people with laser background to the commissioning team.

A: We have discussed with the accelerator team to create a combined commissioning schedule including both the accelerator and photon beamline commissioning. There will be two commissioning phases. The main task for the beamline commissioning in the first phase is the beamline alignment, delivering the beam to the end-station, and the first experiment demonstration. For the second phase, the task is the optimization of the beamline performance to acquire the specifications of the beamline.

A joint commissioning team for the beamline and accelerator is established. The team includes persons from beamline physics, FEL physics, diagnostics, mechanics, control, and accelerator-related systems. The joint commissioning team holds regular meetings to summarize work and assign tasks.

During each commissioning period, there must be staff on duty from beamline physics and FEL physics. The entire commissioning process shall be recorded in the E-Log and summarized during shift handover.

The first-phase beam commissioning of FEL-II is scheduled to start from the beamline commissioning (T0). The commissioning conditions are shown in the following.

item	**value**
Photon energy	200 eV
Repetition rate	10Hz @ T0, 10kHz @ T0+3
Pulse energy	10 μJ

R1-9: Basic parameters of all optics (e.g., shape, mirror length, grazing angle, substrate/ coating materials, cooling systems, etc.) and those of X-ray beams in the several critical locations should be summarized in tables as essential materials for TAC.

Jiahua Chen: Jiahua Chen:

Mirror	Location	Shape	Optical length	Grazing angle	Substrate/ coating	Cooling system
M1	165m	Plane	700 mm	10 mrad / 5 mrad	Si/ B_4C	Water/In-Ga medium
M2a	168	Plane	700 mm	8.7 mrad	Si/ B_4C	Water/In-Ga medium

M2b	172.05	Plane	700 mm	3.7 mrad	Si/ B_4C	Water/In-Ga medium
PM-PGM	- (1)	Plane	750 mm	15 mrad / - (2)	Si/ B_4C&Pt	Water/bottom
PG1-PGM	200 m	Plane	300 mm	-(2)	Si/ B_4C	Water/bottom
PG2-PGM	200 m	Plane	300 mm	-(2)	Si/ B_4C	Water/bottom
ECM-PGM	200 m	Elliptical cylinder	300 mm	15 mrad	Si/ B_4C	Water/bottom
M3a	267 m	Plane	600 mm	17 mrad	Si/ B_4C	Water/In-Ga medium
M3b(ECMH-SSS)	267 m	Elliptical cylinder	600 mm	17 mrad	Si/ B_4C	Water/In-Ga medium
PM-SSS	-(1)	Plane	550 mm	15 mrad / - (2)	Si/ B_4C	Water/bottom
PG-SSS	323 m	Plane	300 mm	-(2)	Si/ B_4C	Water/bottom
ECMV-SSS	323 m	Elliptical cylinder	450 mm	15 mrad	Si/ B_4C	Water/bottom
ECMH-SES	330.8 m	Elliptical cylinder	850 mm	15 mrad	Si/ B_4C	Water/In-Ga medium
ECMV-SES	331.825 m	Elliptical cylinder	650 mm	15 mrad	Si/ B_4C	Water/In-Ga medium
ECMH-AMO	341.75 m	Elliptical cylinder	850 mm	10 mrad	Si/ B_4C	Water/In-Ga medium
ECMV-AMO	343 m	Elliptical cylinder	850 mm	10 mrad	Si/ B_4C	Water/In-Ga medium

(1) The location is variable at different photon energies during energy scanning;

(2) The grazing angle is variable at different photon energies during energy scanning.

2. Systems Enabling FEL Experiment

Starting from the pilot experimental requirements of the Spectrometer for Electronic Structure (SES) and Atomic, Molecular, and Optical Science (AMO) instruments, this session will present the conceptual design of key enabling systems, including photon diagnostics, pump-probe laser setup, timing and synchronization, and the data acquisition (DAQ) framework. The goal is to ensure these systems meet user requirements while remaining scalable and operationally efficient.

CHARGE question: *Advise on how well the current designs of diagnostics, laser systems, synchronization, timing, and DAQ align with experimental requirements. Provide recommendations on improving integration, calibration procedures, and overall performance, especially with respect to time-resolved experiments and data handling requirements.*

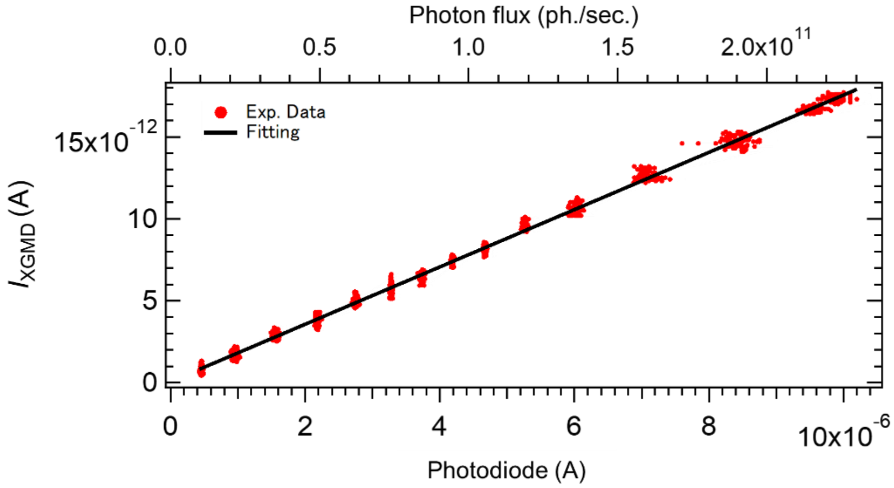
Findings: Yong Wang first presented the SES and AMO end-station x-ray diagnostic systems. There is an impressive range of diagnostics systems: 7 types and multiple units per system, e.g. 16 imagers in the FEL-II beamline. Inspiration and lessons learnt from existing FEL facilities were taken into account for the design. Cameras at the imagers will generally deliver 50 frames/sec, available scintillators will be diamond, YAG and GIG. The scintillators will be removed from the beam depending on rep rate and pulse energies. Jiaming Jiang presented next the pump-probe lasers, their synchronization and first thoughts on commissioning. Each end-station will be equipped with an independent pump-probe laser. These lasers will be in-house developed hybrid fiber-oscillator Yb-CGA/CYA dual crystal regenerative amplifier systems, using nonlinear MPC compression to achieve pulse durations <50 fs and a beam power >100 W at 100 kHz. The demonstration of this laser is planned for summer 2025. To provide awide range of pump laser frequencies tunable OPA systems covering 315nm – 12µm are being developed, while 2nd and 3rd harmonics will be used, too. The laser oscillators are synchronized via stabilized optical fiber links and BOCs.

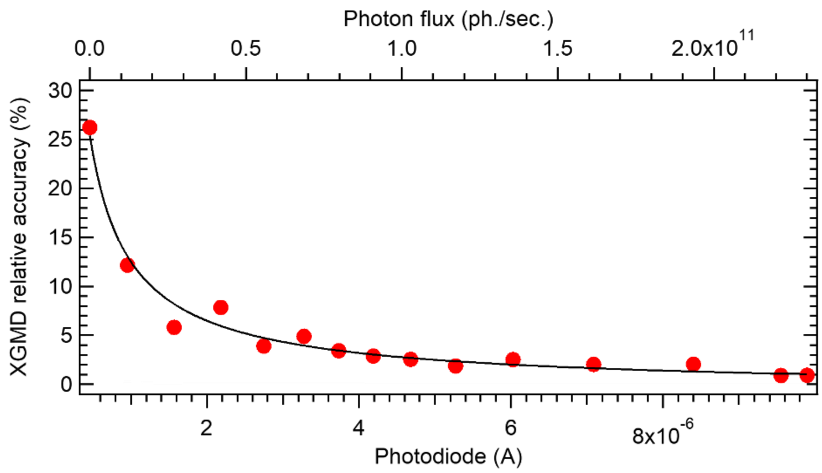
No RF clock signal will be used at the instruments. The science instruments will be equipped with timing tools using spectral encoding. In the last part the IT infrastructure for DAQ and storage of experiment data was shown. It is aimed to provide a readout capacity coping with the data rate of the detectors. 10 Gbit/s links are used for the detectors, data are stored first in an online data storage, and will be later streamed from there to an offline data storage. Event building and first data analysis shall already occur on the online data stream. To identify events at least two systems shall be used. A White Rabbit (WR)-based system will be employed to synchronize the DAQ and shall provide sub-nanosecond accuracy. In addition, a bunch ID system shall be used for commercial detectors. Tests of the WR-based system confirm a jitter of less than 50 fs, and for the bunch ID it was possible to uniquely map signals from commercial detectors at 10 kHz. The control system will employ EPICS and Blue sky. Layout and concept of the controls and DAQ for the first endstations has already started. The DAQ shall be available by the end of 2025. A brief overview of data management and the data storage infrastructure, mainly outlining initial plans for online storage, offline storage, and archiving resources was provided. A policy for how long data is stored at various levels has been developed.

Response to the Charge questions:

- The layout and design of the x-ray diagnostic systems is convincing. TAC notes that it will take time to learn how to use these systems, and that it will be important to define the requirements, setups and details for commissioning of the FEL beam and for first experiments in 2026. A table with the usability ranges of all diagnostic tools in terms of rep rate, pulse energy, mono/no mono and operating ranges could be useful. The repetition rate and the pulse energy will be important parameters for the commissioning of some of these systems, e.g. the GMD commissioning and operation may not work at 10 Hz operation with 1 to 10 μJ pulse energy. Equally screens may have an operation range excluding very small and very high-power beams. For large beam power the response of the screens needs attention, e.g. is cooling needed? We did not hear much about the DAQ interface of the diagnostics systems. This integration and as well the calibration of the diagnostics will be important. Testing some of the devices at SXFEL is good, but extrapolation of these tests to the conditions at SHINE could be a challenge. For example, the raw signal processing of fast signals of XGMD/HAMP in the SXFEL tests will use a complete different DAQ chain that needs to be tested and validated. The understanding of actual diagnostics requirements for the commissioning phase requires close interaction between accelerator and photon-side staff.

The calibration of XGMD has been performed on a synchrotron radiation beamline, during which the photon flux was monitored by a calibrated photodiode. The results are shown below. The output intensity of XGMD shows excellent linearity with the photodiode, which can be transformed to absolute photon flux. The intensity of photon flux significantly affects the accuracy of XGMD, as shown in the lower panel of the graph.





As for the interface between the diagnostics device and DAQ system, the local electronics of all the diagnostics equipment are integrated with the DAQ system via a dedicated data network with 10 Gbps bandwidth (SFP+ Optical interface). We have tested the DAQ system of HAMPs in the low repetition rate (~20Hz), in which the local electronics and computer recorded every waveform acquired by HAMPs. However, such a strategy is not suitable for SHINE which works in high repetition up to 1MHz. In the SHINE project, the local electronics will process each waveform in a real-time mode, utilizing the FPGA module that is integrated in the fast-ADC (sampling rate: 1GS/s; bandwidth: ≥300 MHz). All the waveforms will be transformed into an intensity number that represents the energy of each pulse by an algorithm pre-defined in the FPGA. Only the output intensity results will be collected by the DAQ system, but not the raw data of each waveform, which may fulfill the requirement in the high repetition mode. At the same time, a set of low repetition data (~10 Hz), which is generated by frame extraction or averaging, will also be delivered via the EPICS network for monitoring purposes.

- From the information provided, the laser and synchronization concepts appear to be technically sound. However, the integration and engineering of the pump-probe lasers seem to require still a considerable amount of work. The TAC wasn't sure if the design shown were for proof-of-principle demonstration, or are already engineering designs. Without this knowledge and the knowledge about the size of the available workforce it is difficult to judge if the foreseen 'ultrashort' time-line for laser installation is realistic. We note that details of beam transport (laser-room to laser tables at the instruments and from those tables to the interaction region) were not presented. To be ready for experiments, the following should be planned in parallel: laser delivery from the laser room to the experimental hutch, optical parametric amplification (OPA) and harmonic generation (SHG, THG, FHG), delay lines to adjust the time delay between laser and X-ray pulses. In addition, setting up and optimizing diagnostics (beam overlap, timing tool, etc.) in the experimental hutch will require sufficient time.

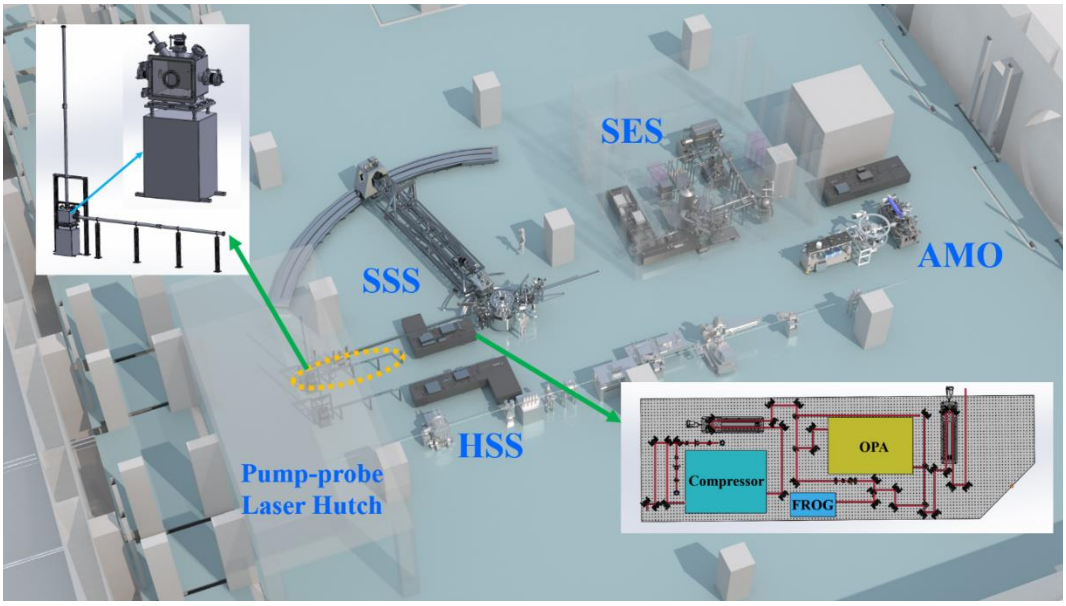
Jiaming Jiang

Thank you for your constructive feedback on the laser system. We have carefully reviewed your comments, and our detailed responses are as follows:

For the design status, we are currently engaged in the engineering designs for each sub-system, clearly distinguishing between proof-of-principle demonstrations and detailed engineering designs, which include the design specifications, tolerances, and integration plans. We look forward to sharing these details in our upcoming meeting.

For the workforce allocation, our laser systems team currently has five full-time researchers. We also have close collaborate with the femtosecond synchronization team from the SHINE accelerator division, and Shanghai Institute of Optics and Fine Mechanics. We acknowledge your concern about the feasibility of the foreseen timeline for laser installation. To address this, we will conduct a thorough review of our installation schedule, taking into account the current design maturity and the size of our dedicated workforce. We also plan to recruit additional engineers with expertise in laser transport and diagnostics to ensure we meet our project milestones.

For beam transport details, we apologize that the details were not presented due to the time limitation. We have developed detailed optical layouts for transport from the laser room to instruments and interaction regions, including specifications for vacuum systems, optical elements, optical path design, and safety considerations. For instance, the optical path for the SSS end-station is fully designed and includes essential components like compressors, Optical Parametric Amplification (OPA), and optical delay lines. Moreover, the beam will be transmitted from the second-floor laser laboratory to the experimental station through vacuum pipes, with the optical path incorporating relay imaging and an active pointing stability module. To enhance overall stability, the deflection cavity is fixed on a marble base. Please refer to the attached layout diagram for further details.



Finally, for parallel planning, we fully concur with your recommendation to plan the laser delivery, commercial OPA, and harmonic generation (SHG, THG, FHG), and delay lines in parallel with the setup and optimization of diagnostics in the experimental hutch. We have already initiated these parallel efforts. Furthermore, we are actively planning the setup and optimization procedures for essential diagnostics such as beam overlap and timing tools within the experimental hutch, ensuring sufficient time and resources are allocated for these critical tasks.

- The DAQ and timing systems could pose severe challenges to SHINE operation, both due to the high data rates and the high repetition rates. The brief material the TAC has seen at this meeting is not sufficient in order to provide an in-depth analysis and provide proper recommendations. We provide however below a couple of suggestions that might be useful to design, build and commission the system. For setup, commissioning, and operation tasks in 2026 the control system and a bare DAQ system need to be functional. This system requires testing prior to any experiments with x-ray beam. The amount of time required to properly setup the motor control system for the complex system of FEL-II and the three science instruments should not be underestimated.

Reply:

The DAQ and timing systems indeed present significant challenges. A comprehensive report on these topics will be presented at the next TAC meeting.

（1） We have conducted extensive laboratory tests of DAQ and timing systems, including evaluations of the DAQ and timing software, as well as data management tools. We also thoroughly examined the software, servers, and storage solutions under high-throughput data conditions. For example, the bare DAQ software for the Jungfrau megapixel detector is intended to meet the requirements of the CDS and HSS endstations at data rates up to 2.2 kHz. The DAQ system's hardware, including both network and storage components, is capable of handling data throughputs of up to 100 GB/s.

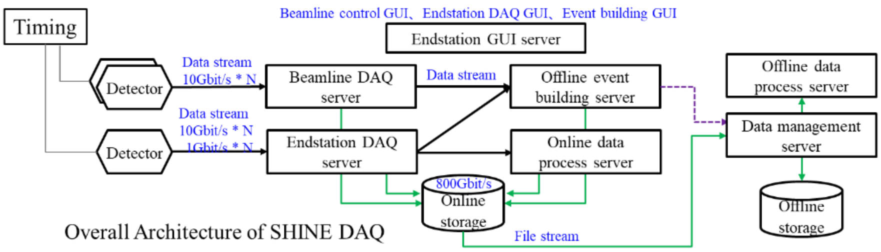


Fig.1 DAQ Architecture for beamlines and endstations

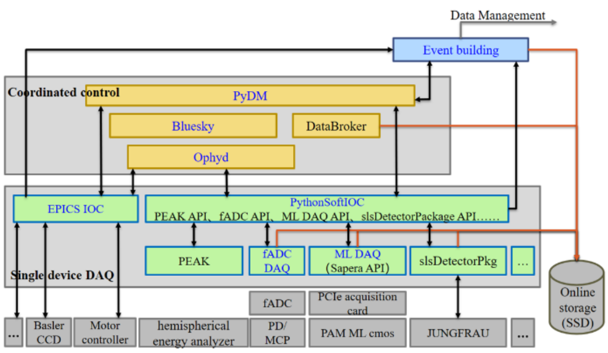


Fig.2 Architecture of DAQ Software

（2）The initial version of DAQ system for SES end-station was developed in 2024. Following the installation of the SES end-station and the optical laser, we will begin the software’s online installation and testing. After this, the DAQ will be continually tested with control system before commissioning phase. The initial version of DAQ for AMO end-station is scheduled for completion by the end of 2025 and will subsequently undergo a similar testing process to the SES end-station.

(3) In addition, we have developed DAQ for some diagnostic equipments based on the same architecture this year. Online software debugging will be conducted after the diagnostic devices are installed by the end of 2025. Additionally, the timing control software was developed and tested by the end of 2024, and is ready for deployment upon the completion of the associated hardware installation.

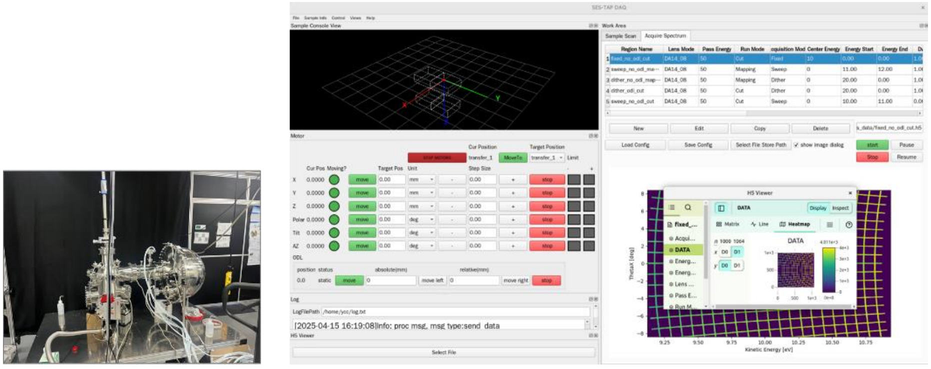


Fig.3 Progress of DAQ software for SES

Observations and comments concerning the control, DAQ, timing, and data management systems (bulleted list for better separation of topics)**:**

- The needs and the layout for a full rep rate DAQ and data storage system need to be confirmed, including estimates for data volume and processing for user experiments and the definition of hardware and technologies. Peak and average bandwidths between the different data sources/sinks must be estimated for a realistic user operation. While the DAQ requirements for the 2026 experiments at 10 Hz will be relatively small, the system needs to be scalable to operation of six instruments and the MHz repetition rate. A later change of architecture would be disruptive. SHINE should establish a data management and service software system that covers the entire data lifecycle, including capabilities and functionalities for data acquisition, storage, processing, long-term preservation, and distribution. A unified software architecture and metadata specification are suggested, along with centralized data management.

Reply:

(1) In-depth analyses have been conducted, accompanied by thorough discussions with the teams of each endstation to define the servers, networking, and storage of their experimental stations. Detailed information will be presented at the upcoming TAC meeting.

Table 1 Data storage for beamlines and endstations

Type	default quota	Nominal	Phase-I	Duration	Storage type	File System
Online Storage	/	5+5PB	1+1PB	7 days	SSD	Lustre, GPFS, etc.
Offline Storage	1.5 × raw data volume	50+50PB	8PB	6 months	HDD	Lustre, GPFS, etc.
Archiving	/	500PB	/	10 year	Tape	
Public zone	100GB	500TB	/	as long as account exist	HDD	
Temp. zone	10TB	500TB	/	7days	SSD	

(2) The data throughput of endstations for imaging and scattering experiments is constrained by the 2D pixel detectors, with a maximum foreseeable rate of 10 kHz@megapixel. At the spectroscopy endstation, the maximum required data acquisition rate reaches 100 kHz; however, the corresponding data volume remains relatively small. For future scenarios with even higher repetition rates, FPGA-based data processing will be implemented to alleviate the demands on downstream software development.

Table 2 Data throughput and storage requirement of SHINE endstations

	Total throughput (GB/s)	**Online storage (TB)**	**Offline storage (TB)**
AMO@4#	**0.5**	**18**	**100**
SES@4#	**<1**	**<10**	**<100**
SSS@4#	**31**	**20**	**<100**
HSS@4#	**3.2**	**35**	**720**
CDS@5#	**22**	**1847**	**36945**

(3) To ensure the high data rates, high-performance DAQ core switches manufactured in China have been deployed, capable of handling peak data throughput. The performance of the networking, HPC, and storage infrastructure is easily scalable through the addition of hardware components.

Each DAQ core switch offers a switching capacity of over 1,600 Tbps and a forwarding rate of 460,000 Mbps. A single core switch can accommodate up to 8 board cards, each card providing 48 ports at 100 Gbps, yielding a total of 768 100Gbps ports that are fully available on the DAQ core switches. Additionally, the switches support 400 Gbps board cards. The system is compatible with the RDMA over Converged Ethernet (RoCE) protocols, both v1 and v2.

(4) SHINE has developed the data management software to establish a comprehensive data management and service system that spans the entire data lifecycle. This includes capabilities for data acquisition (DAQ), storage, processing, long-term preservation, and distribution, in accordance with recommended best practices. In particular, customized development is currently underway based on the DOMAS scientific data management framework, developed by the Institute of High Energy Physics of the Chinese Academy of Sciences. The framework is being tailored to accommodate specific data scenarios and can be seamlessly integrated with acquisition systems at beamlines and endstations, with the goal of providing unified management and services for experimental data.

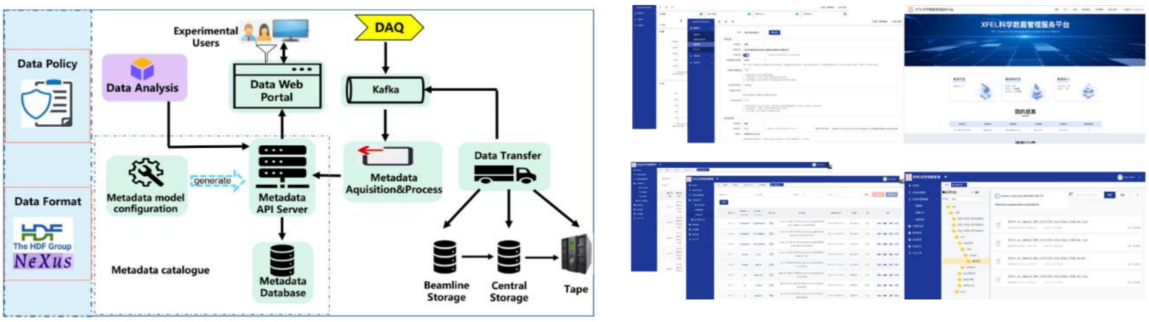


Fig. 4 SHINE Data Management Software in collaboration with IHEP

The DAQ system is designed to collect scientific metadata and writing experimental data files to an online fast storage system during experiments. The scientific metadata are subsequently received by the data management software and recorded in a database along with other relevant information. Within 7 days after the experiments, the data files are migrated from the online fast storage to an offline massive storage system.

Moreover, the data management software integrates management metadata, such as proposal and user information—from external systems. By linking this information with dataset identifiers, the system maintains a complete metadata set for each dataset in a MongoDB-based repository, thereby establishing a comprehensive metadata ecosystem for all experimental data.

In addition, a dedicated data service portal has been developed, offering functionalities such as data search, online visualization, download, access control, and distribution. This ensures users have convenient, secure, and efficient access to their experimental data.

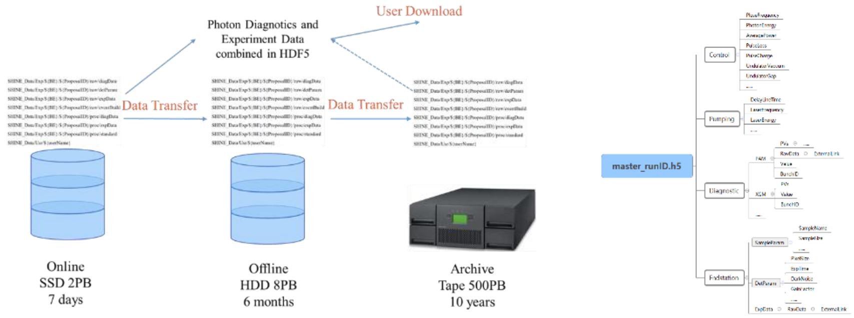


Fig.5 Data format and policy of SHINE

- Following definition of the network technology and topology, the storage layout, DAQ server node number and distribution has to be prepared, and the core part of the hardware should be procured as soon as possible. Also, the build-up of (in house) know-how is as important as the hardware itself. The mentioned non-proprietary solutions like BeeFS or Lustre allow flexibility and scaling. To setup, commission and operate these systems the team need to require the relevant expertise, which will take time.

Reply:

(1) On day one commissioning, two beamlines and five experimental stations will be brought online. For beamline diagnostic devices and experimental station detectors, acquisition will be handled by DAQ servers in the computer room if the detector has a network interface. For devices without network interfaces—such as those using PCIe—data will be collected using local industrial PCs.

As an example, the FEL-II beamline includes seven types of diagnostic devices, three of which are equipped with detectors that have network interfaces. Since not all devices of the same type are used simultaneously and to use resources efficiently, each device type is currently assigned one high-performance data acquisition server, meeting basic data acquisition requirements. For the other four device types, due to limitations in transmission distance, each device is equipped with its own local industrial PC for data collection.

The first three experimental stations to be commissioned at FEL-II are all spectroscopy stations with relatively low data rates. As a result, each will have its own data acquisition server.

The diagnostic devices at the FEL-I beamline are similar to those at FEL-II. However, FEL-I has two experimental stations that require high-frame-rate area detectors (JUNGFRAU): one station uses a 4-megapixel detector, while the other uses a 0.5-megapixel detector. Drawing on previous experience, each of these stations will be equipped with a dedicated high-performance server cluster. Additional server capacity will be added to meet the growing computational demands in the future .

(2) For the most important file systems, we would like to deploy the commercial distributed file system (candidate may be lustre or GPFS) to get more professional support to ensure greater stability and scalability. The knowledge on the file system needs to be accumulated over years of operation, as suggested.

- Providing a more detailed description of the technical solution for the fast access storage system, as well as the plans for data analysis and processing, and as well about the distribution of user data will enable the TAC to make more qualified statements.
- Tape storage is a reliable solution for long-term storage in the hierarchical storage architecture of large volume FEL data. We haven't seen details for such a tape storage system. However, it is our understanding that SHINE must preserve all scientific data and make these publicly available after an embargo period. This corresponds to a huge requirement to data storage. TAC would like to understand how SHINE will approach this challenge. This topic might as well address the data policy for long-term data storage, the accessibility by the public, and if there will resources for users to access and transfer data.

Reply:

(1) For data acquisition (DAQ), each experimental hall will be equipped with 8 CPU nodes and 2 GPU nodes to support online data analysis. A one PB SSD-based fast storage system is deployed for data cache with more than 100GB/s rw speed and IOPS (more than 1M).

The commercial distributed file system will be adopted to ensure professional support and enable easy scalability. Both the 100 Gbps Ethernet and 200 Gbps HDR InfiniBand networks will be supported.

For offline data analysis, over 8 PB of storage and more than 20 HPC nodes will be deployed. The DAQ network, core control network, and on-site device core network at shaft 4 are scheduled for completion by July 2025, while by March 2026 at shaft 5. The DAQ servers, online storage, and online HPC resources will be ready by December 2025 at shaft 4, while by July 2026 at shaft 5.

(2) SHINE plans to establish a tape storage system to handle its large data volumes. Enough space and power capacity will be reserved in the data center with a potential total capacity of up to 500 PiB. The tape storage system will comprise two components: hard disk drives (HDDs) serving as a cache layer, and tapes functioning as the primary storage medium. All metadata will be available via the file system, enabling users to locate and request files at any time. It is important to note that data retrieval speeds will be limited by the inherent performance characteristics of the tape drives.. The tape deploy zone was already completed in the data center at shaft 5.

Fig. 6 Layout and photo of main computer room (with space reserved for tape archive) in Shaft 5

(3) All scientific data will be preserved for more than a decade and will become publicly accessible after an embargo period of two to three years, following a model like that of the Euro-XFEL. The data policy has been discussed, and a draft has been prepared in collaboration with other synchrotron radiation and neutron source facilities in China, including HEPS, SSRF, HALF, and CSNS. Once approved by the relevant government authorities, these scientific data will be made publicly available by applicable laws and regulations in China. To accommodate the vast volume of accumulated data, backup and analysis may be carried out at other data centers under designated protocols.

(4) We do not have any plan to supply the servers or workstations for direct data transfer via USB or other hard drivers. Only via the website, the users can download the data. The related data directory will be mounted on the web server with read-only permissions, allowing users to access and download data through the SHINE-provided web portal.

(5) SHINE has established a strong collaboration with other advanced light source and neutron source facilities in China, including the High Energy Photon Source (HEPS), Shanghai Synchrotron Radiation Facility (SSRF), Hefei Advanced Light Facility (HALF), China Spallation Neutron Source (CSNS), etc. A scientific data and software union has been established by the facilities to meet the challenge of large-scale scientific data.

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Fig. 7 Scientific Metadata standard for Advanced light source& Neutron source in collaboration with IHEP, USTC, SARI etc.

- SHINE may benefit from a strengthened inter-facility collaboration in areas such as control systems and data services.
- There are a large number of environmental parameter sensors in the beamline and experimental station, and it is necessary to ensure that all monitoring parameters can be integrated into the control system of the entire facility (for example, by connecting to EPICS), in order to facilitate future feedforward, feedback, and data correlation analysis. These parameters should be recorded in the files saved by the users, but also in a facility wide archive/data-base system with full history availability. Such a system will be important to track long term drifts, etc.

Reply: We completely agree with your viewpoint and are actively working on the relevant design tasks. The environmental monitoring system has already been developed and will be integrated with the DAQ system.

• Histories of slow (low-volume) data like from beam-diagnostics or environmental sensors shall be readily available for analysis on disk for long periods (on the order of years), much longer than the high-volume user data which will need to be transferred to tape more quickly within weeks or months.

Reply: As suggested, these slow (low-volume) data will be stored on both disk for fast access and tape for archiving.

• The timing system based on White Rabbit (WB) technology is a solid solution. Still, at the boundary between the timing and DAQ systems and at the repetition rates involved, things can easily go wrong, especially with commercial cameras where proprietary links make early pulseID tagging impossible. Software tagging can plausibly only work at the ms scale, so below 1kHz, but this has to be tested and confirmed, with a realistic load at the DAQ machine. Trigger number (frame#) to pulseID matching should be the last resort, as it is prone to catastrophic failures over long runs.

Reply: Thank you for the suggestion. Extensive testing is currently being conducted on both commercial and in-house developed detectors.

Commercial cameras are triggered by the SHINE WR Node, and data packets are subsequently received in sequence by the DAQ system. The SHINE WR Node simultaneously collects BunchIDs at both the start and end of the trigger event and transmits them to the DAQ via UDP. The frame numbers of UDP BunchID packets start at zero and increase sequentially with each acquisition, allowing the DAQ to quickly detect any missing BunchIDs during UDP transmission. Most detectors have their own timestamps, which facilitates data integrity checks and helps identify possible data loss. For certain detectors that do not embed timestamps in their data streams, the data is typically transmitted over highly reliable channels such as PCIe, making data loss extremely unlikely. Therefore, the number of camera data packets and BunchIDs should match.

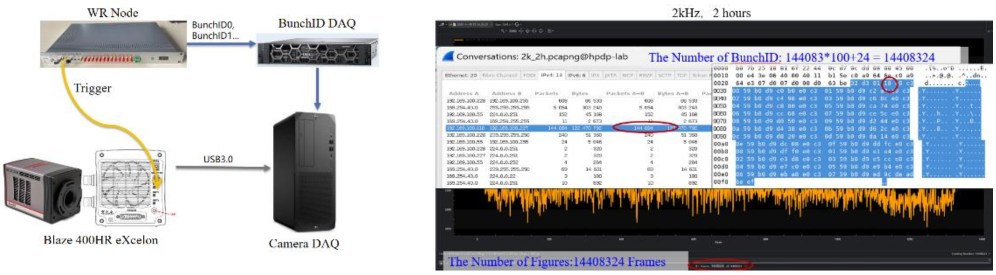


Fig.8 BunchID acquisition for commercial camera

- The (White Rabbit derived) trigger system and the flexibility in terms of trigger rates and trigger rate domains has not been discussed. Here careful planning is important to avoid unnecessary constrain down the road.

  Reply: Thank you for the recommendation. The SHINE WR timing system supports a maximum trigger rate of 1 MHz and provides integer division frequencies such as 1 Hz, 2 Hz, 4 Hz, 5 Hz, 10 Hz, ..., up to 400 kHz and 500 kHz. In addition, some special frequency patterns can be generated using a masking sequence. The trigger delay range spans from 50 ps to 1 s, with a configurable step size of 50 ps. Similarly, the trigger pulse width is adjustable from 50 ps to 1 s, also with a step size of 50 ps.

- We haven't heard about the FTE resources allocated to data topics. TAC points out that DAQ, data analysis and data storage are important requirements for a high repetition rate FEL as SHINE and require sufficient manpower investment. Consider here algorithm development and software coding, too.

  Reply: As is well known, large scientific facilities such as the European XFEL and Diamond Light Source maintain strong control and data science teams, with dozens of full-time staff, along with postdoctoral researchers and students. Currently, the SHINE data group consists of twelve staff members and four students. A detailed WBS has been prepared to meet the manpower requirements. Recruitment will be initiated once the WBS is approved by SHINE leadership.

- We haven't been informed about cybersecurity measures. However, data security should be taken seriously for a large facility such as SHINE, and security protocols within a cybersecurity structure in accordance with applicable standards should be created.

  Reply: Thank you for the comments. Data security and cybersecurity are critical for large scientific facilities. A comprehensive lifecycle data protection strategy will be established. As it is well known, cybersecurity must strike a balance between openness and security.

  First, all practices will comply with the laws and regulations outlined in China's Multi-Level Protection Scheme (MLPS) 2.0. Second, the network architecture will be divided into multiple zones with varying security levels, from the lowest (open zone) to the highest (restricted zone). Network and data-related services will be deployed within appropriate zones based on their sensitivity. The network and data-related services will be mounted in different security zones. Customized access control policies will be applied in each zone. For example, a zero-trust security model will be implemented in the highest security zone. Third, for the user's login to access the offline data, such as the HPC, etc., strong authentication measures will be enforced, including the use of complex passwords and mandatory Multi-Factor Authentication (MFA).

In addition, collaborations have been initiated with IHEP to enhance cybersecurity strategies. Finally, the policies are crucial for the data and cyber security. (By Weijia and Wujun)

Recommendations:

R1-10: We recommend to define the requirements for scientific computing and data analysis, to estimate based on these requirements the software and hardware resource needs, and to determine the technical architecture for such a system as soon as possible, ensuring sufficient resources for data analysis when SHINE starts operation.

During our technique design, we have defined the requirements of scientific computing and data analysis as follows.

Table 3 Requirements for scientific computing and data analysis

	Short Term	Long Term
Data Volume（GB/s）	18	24
Effective Collection Time (hours/experiment)	42	72
Online Storage (PB/experiment)	3.6	6.2
Experiment Frequency (times/year)	15	25
Offline Storage Capacity (PB/year)	53	153
Online Analysis Timeliness (seconds/minutes)	seconds	minutes
Online Computing Power Requirement (TFLOPs)	4	60

As an example, the requirement of data transmission and storage for CDS endstation is listed as the follows. All the spectra data will be collected from the Jungfrau area-detector. The requirements of online data analysis is low, while the real-time display of the data is necessary.

Table 4 Requirements for data transmission and storage for CDS endstation

	2D area detector
Pixel numbers	≥ 512 × 1024（3）
Frame rate	Typically, 10 kHz
Data throughput	15 GB/s
Data per hour	52.7 TB
Acquisition time per round	8 h

Data per round	421.8 TB

Suggestions for next meeting(s)

The TAC suggests to include in the material of the next TAC meeting:

- presentation of the milestone list including achievements and delays.

We’re checking with our management board. We had some discussions on the latest completed milestones and possible delays. The TAC local organization team will prepare the list and send to all our TAC members.

- presentation of the commissioning plan (various aspects), and a

The detailed commissioning plan (aligned with the machine side) is under preparation. We’ll pack it and upload to the indico website.

- discussion / presentation of science priorities and implications on technical / machine priorities.

These are necessary for an efficient TAC meeting. We’ll load all the materials at least 2 weeks before the TAC meeting. The indico or confluence link will be sent our TAC members soon.

More general and specific observations and comments

- How will the repetition rate be increased from Mar 2026 (10 Hz) to end 2026 (100kHz)? Most users may be interested in high time resolution, a high signal-to-noise (S/N) ratio, and good statistics of their data, the stability and reliability of the beam would be the users' main concern. While the currently planned flux of 10^{11} photons/pulse should ensure sufficient statistics for single-pulse pump-probe measurements, the planned rapid increase in repetition rate (from 10 Hz in March to 100 kHz by summer 2026) raises concerns how experiments could be performed at the high rate.. While operation at few 100 Hz may ease measurements and repetition rates of few kHz would be manageable for DAQ systems, the increase to 100 kHz and even MHz pose real challenges and may require more than a few weeks to achieve. Radiation damage could become a critical issue at high repetition rates, so mitigation strategies should be developed.

Jie Wang:

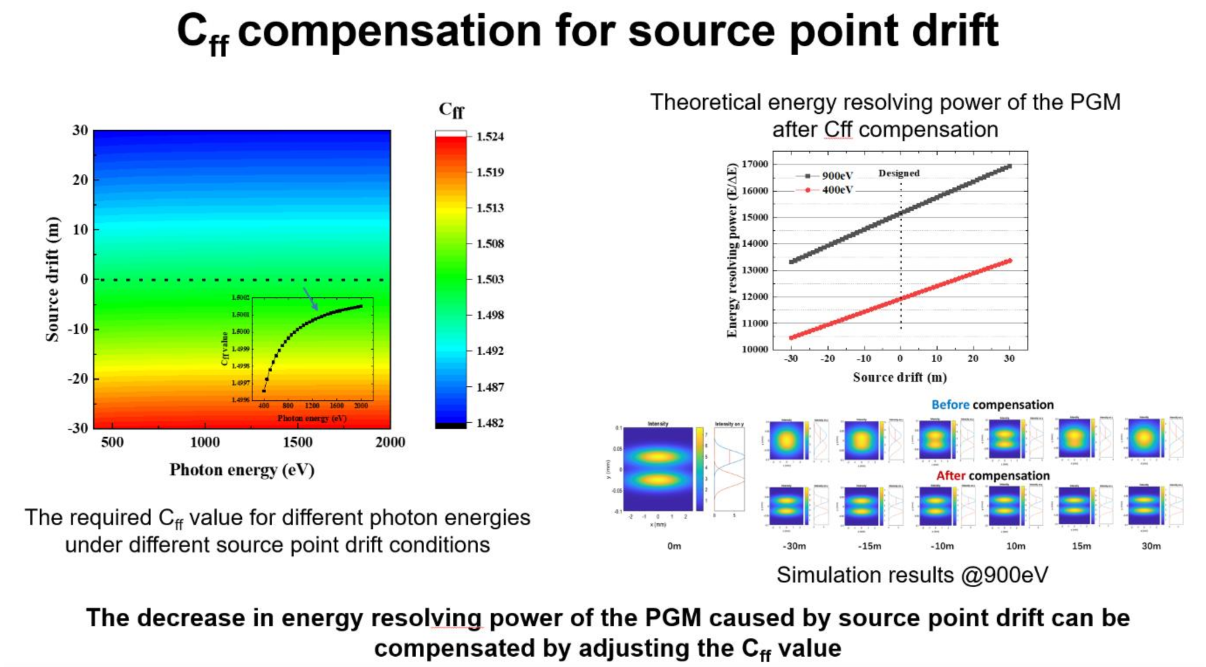
1）By the end of 2024, the SHINE injector operated at an electron bunch energy of 100.2MeV, a repetition rate 100.3kHz, and a peak current 12.8A (bunch charge 51pC) of a single pulse. We believe that the injector will provide an important base for future high-repetition operation. And yet, a gradual ramp-up process of repetition rates starting from 10Hz will be controlled. Special attention to minimizing the bunch loss should be given throughout the process.

2）Increasing the repetition rate is rather important to get good statistics, especially for time-dependent studies with a pump and probe scheme. Normally, the electron time of flight is well below 1 μs, while ions can easily be extracted within 10 μs. Thus, for experiments with detectors that use MCP to measure the time of flight or that are equipped with a delay-line anode to get additional position information, it is possible to perform experiments with 100 kHz repetition rate. Taking COLTRIMS (cold-target recoil ion momentums spectroscopy) as an example, with the coincidence technique, experiments can be performed even with more than 1 MHz repetition rate at PETRA III.

ITEM 3: Talk – FEL-II beamline design, stability, particle- free environment

- The source point in the FEL-II undulator is shown as a fixed point in this presentation. However, it can move by +/- 30m and still the PGM will provide good resolution, as was analyzed in simulations (results not part of this presentation).

Chaofan XUE:



- Need a detailed list of optical elements that includes dimensions, optical parameters, and other relevant characteristics (e.g., their location along the transport system).

  Similarly, details about the beamline diagnostics tools (e.g. screens), including location, expected beam size, and resolution, are needed.

The following table shows the detailed information of optical elements.

Mirror	Location	Shape	Optical length	Grazing angle	Substrate/ coating	Cooling system
M1	165m	Plane	700 mm	10 mrad / 5 mrad	Si/ B_4C	Water/In-Ga medium
M2a	168	Plane	700 mm	8.7 mrad	Si/ B_4C	Water/In-Ga medium
M2b	172.05	Plane	700 mm	3.7 mrad	Si/ B_4C	Water/In-Ga medium
PM-PGM	- (1)	Plane	750 mm	15 mrad / - (2)	Si/ B_4C&Pt	Water/bottom
PG1-PGM	200 m	Plane	300 mm	- (2)	Si/ B_4C	Water/bottom

PG2-PGM	200 m	Plane	300 mm	-[2]	Si/ B_4C	Water/bottom
ECM-PGM	200 m	Elliptical cylinder	300 mm	15 mrad	Si/ B_4C	Water/bottom
M3a	267 m	Plane	600 mm	17 mrad	Si/ B_4C	Water/In-Ga medium
M3b(ECMH-SSS)	267 m	Elliptical cylinder	600 mm	17 mrad	Si/ B_4C	Water/In-Ga medium
PM-SSS	-[1]	Plane	550 mm	15 mrad / -[2]	Si/ B_4C	Water/bottom
PG-SSS	323 m	Plane	300 mm	-[2]	Si/ B_4C	Water/bottom
ECMV-SSS	323 m	Elliptical cylinder	450 mm	15 mrad	Si/ B_4C	Water/bottom
ECMH-SES	330.8 m	Elliptical cylinder	850 mm	15 mrad	Si/ B_4C	Water/In-Ga medium
ECMV-SES	331.825 m	Elliptical cylinder	650 mm	15 mrad	Si/ B_4C	Water/In-Ga medium
ECMH-AMO	341.75 m	Elliptical cylinder	850 mm	10 mrad	Si/ B_4C	Water/In-Ga medium
ECMV-AMO	343 m	Elliptical cylinder	850 mm	10 mrad	Si/ B_4C	Water/In-Ga medium

	Diagnostic tools	**Position (m)**	**Function**		**Spot size/mm**
1	Imager0	83.62		Imager	3.46
2	Imager1	110			4.56
3	GMD+HAMPs 1	115		X-ray Gas Monitor Detector & Huge Aperture Open Multiplier	7.6 @6σ
4	PES1	120		Photon Electron Spectroscopy	8.6@6σ
5	Beamlost Monitor(BLM 1)	160.5		Beam Lost Monitor	6.652@6σ
6	Imager 2	161			6.53
7	Imager 3	166.6		Imager(Covering the direct incident beam and reflecting beam)	6.9

8	Image 4	169.1		Imager(Covering the the direct incident beam and reflecting beam of M2a mirror)	7.01
9	Image 5	175.6		Imager(Covering the the direct incident beam and reflecting beam of M2b mirror)	7.28
10	BLM 2	195			5.376@6σ
11	Image 6	195.6			8.1
12	Image 7	207.5			3.282 @6sigma
13	Image 8	270		Imager(Covering the the direct incident beam and reflecting beam of mono and pink branch)	11.19
14	Monochromatic energy resolving power diagnose	295.7	（mono）		4.33×0.03
15	BLM 3	311	(mono)		0.82@6σ
16	BLM 4	311			0.82@6σ
17	XGMD+HAMPs2	314			22 @6σ
18	HAMPs3	314	(mono)		22 @6σ
19	Image 9	316	(mono)		
20	Image 10	317			13.09
21	Pulse arrival time monitor(PAM 1)	321.5	(mono)	SSS Pulse Arrival Time Monitor	
22	Image 11	322	(mono)		13.34
23	Image 13	322			13.34
24	Image 12	324	（mono）		12.53
25	Image 14	325			12.53
26	WFS1	327		SSS Wavefront Sensor	8.5@4σ
27	PAM2+Image 15	330			
28	Image 16	335	（mono）		13.88
29	WFS2	337		SES Wavefront Sensor	5.5@4σ
30	Image 17	339.5		Imager(blocking the zero order diffraction beam of IEB and observing the direct incident beam to AMO)	14.07
31	PAM 4	347.8		AMO Pulse Arrival Time Monitor	
32	PAM3	334.3	（mono）	SES Pulse Arrival Time Monitor	
33	WFS3	345		AMO Wavefront Sensor	5.5@4σ

34	PAM 4	347.8		AMO Pulse Arrival Time Monitor	

The previous table shows the detailed information of diagnostic tools.

- A fast kicker was mentioned to use all the FEL lines together; will the final actual rep rate at the experiments then be divided by a factor of 3 (or more)?

ITEM 4: Talk - Systems enabling FEL Experiments

- To allow TAC to give a better assessment, it would be beneficial to reference publications and be specific which laser system will be installed. The top right figure on page 40 showing the layout of the laser system seems to be published in "J. Song et al., Opt. Lett.(2023), doi: 10.1364/OL.484843", while the figures below showing the results seem to belong to a laser system which has an additional two-stage Yb:YAG single pass amplifier, published in "L. Shen et al., Opt. Express, (2025), doi: 10.1364/OE.551156" .

Jiaming Jiang:

Reply: We thank the TAC's suggestion regarding the referenced publications, the two publications mentioned above were published by our collaborating team. For the primary design, a single-stage regenerative amplifier was intended to achieve hundred-watt-level power output (demonstrated in "J. Song et al., Opt. Lett. (2023), doi: 10.1364/OL.484843"). However, recognizing potential technical challenges, we have also incorporated a backup solution based on a two-stage traveling-wave amplifier as demonstrated in" L. Shen et al., Opt. Express, (2025), doi: 10.1364/OE.551156". The current laser system is being integrated based on the design in the first paper. However, the space has been reserved inside the laser for the amplification module described in the second paper. This allows for the addition of a traveling-wave amplifier if the single-pass regenerative amplifier fails to achieve the 100W output.

- For facility operation and fast troubleshooting laser diagnostics both in the laser room and close to the instruments are beneficial. What diagnostics are planned?

Reply: Thank you for your feedback. We agree that fast laser diagnostics and troubleshooting are crucial for efficient facility operation. To this end, we are planning a comprehensive suite of diagnostics both in the laser room and strategically located close to the instruments. This will include, but not be limited to: the laser power, full beam profile, spectral characterization, pulse duration, beam pointing stability etc. Part of these diagnostics such as the laser power and beam profile will serve as online monitors, enabling real-time tracking of laser status.

- Is any integration of the laser system to the instrument control system planned ? (for example, to allow users to steer and attenuate the beam, select pulse repetition rate, control polarization, select pump-probe delay)

Reply: We are currently planning the integration of the laser system with the instrument control system. Our goal is to provide users with intuitive control over key laser parameters, including:

1) Remote beam alignment and adjustment capabilities: Users will be able to remotely fine-tune the laser beam's position and direction.

2) Software-controlled attenuation of the laser power: Laser power can be adjusted precisely through the control software.

3) Selection of the available pulse repetition rates: Users will have the ability to choose from a range of available pulse repetition rates.

4) Automated control of the laser polarization: The laser's polarization can be automatically controlled *via* the software.

5) Precise and user-friendly control of the optical delay stages: The system will offer precise and user-friendly control of the optical delay stages.

The specific implementation details and user interface are currently under development.

- Performance plots over a few hours were shown. What about long-term stability and uptime? Are there plans to have some redundancy?

Reply: In the presentation, we only presented test results over a few hours. However, actually, extended-duration testing (24-48 hours) conducted on the SXFEL laser system has indicated time drift compensation results at the ~5 fs level. We will subsequently perform even longer-term testing on SXFEL to thoroughly evaluate the system’s long-term stability and reliability. In addition, we will improve the stability of the environment and cover the laser table to enhance stability and isolate it from environmental disturbances.

- While the laser-oscillators are synchronized it is unclear if any drift stabilization of the laser transport all the way to the interaction point is planned. Is it?

Reply: We have a dedicated plan for drift stabilization along the entire laser transport chain to the interaction point. In addition to the synchronization of the laser oscillators, we have developed a feedback control module based on the BOC (Balanced Optical Cross-Correlator) method to actively monitor and compensate for the timing drift of the laser amplifier output pulses. This module helps to maintain long-term stability throughout the transport system.

- How are laser-safety aspects handled, especially at the instruments?

Reply: Laser safety is our first priority which we are considering. We are implementing a multi-layered safety approach, including:

1) The beam paths at the instruments will be fully enclosed and interlocked to prevent accidental exposure.
2) All stray beams will be carefully controlled and terminated with appropriate beam dumps.
3) Access to the experimental hutches during laser operation will be strictly controlled through interlock systems and safety protocols.
4) Comprehensive laser safety training will be mandatory for all users before they are permitted to enter the laser areas or operate the laser systems.
5) Accessible emergency stop buttons will be located throughout the laser room and experimental areas.
6) Visual and audible warning systems will be in place to indicate laser operation.

Annex:

Specific questions placed in the talks

File on FEL-II beamline design, slide 65:

- Q: What is requirement of the temperature stability of the PGM for guaranteeing the multi pulse high energy resolving power? A: No answer.

- Q: How bad does the vibration, temperature or ambient pressure influence the beam stability? What measures have been taken to solve the problems?

A: Compare the amplitudes of vibration related movements to your stability criteria. If they exceed few percent, you should consider to take actions.

- Q: What environmental parameters are monitored in your facility? for SHINE, are the monitoring points too sparse or too dense? A: No answer.

File on Systems enabling FEL experiments (AMO&SES), slide 34:

- Q: Shall the GMD and/or HAMPs always work at high repetition rate, or just work during experiment?

A: The gas-based online diagnostics XGMD / HAMP shall always operate at the same rate as the x-ray pulses are delivered because the pulse energy of each pulse must be measured individually (shot-to-shot detection). Additionally, there shall bean absolute calibration of the pulses which is usually performed with a slower detection system in the gas-based diagnostics system, integrating over many pulses.

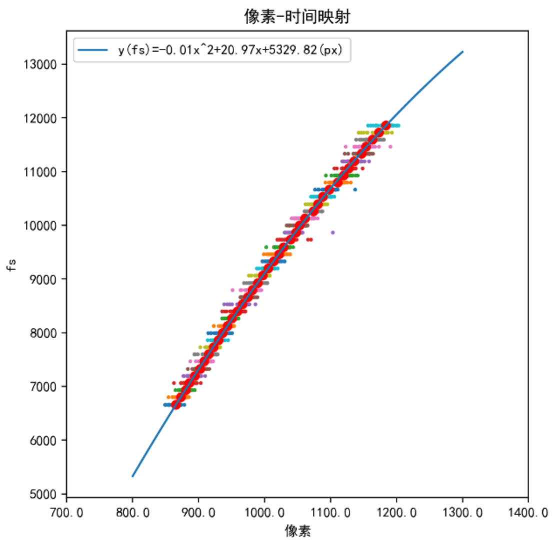
Thanks for the suggestion. The GMD/HAMPs always work at the same rate of FEL. However, due to the huge amount of data in high repetition rate, the data will be stored only upon users' demand, such as during the experiments. At the same time, a set of low repetition data (~10 Hz), which is generated by frame extraction or averaging, will also be delivered via EPICS network for monitoring purposes.

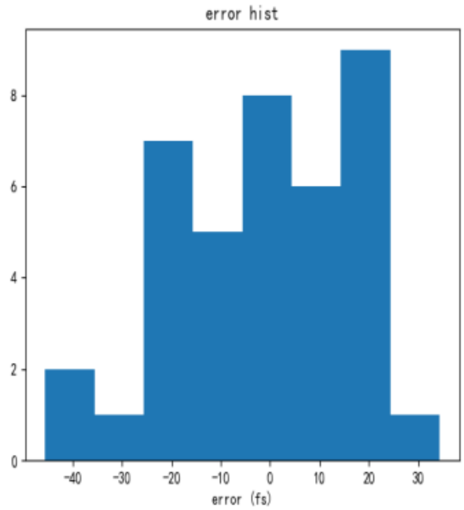
- Q: We calculated PAM accuracy by drift between average of 50 pulses for each delay line and the fitting curve. Is this calculation correct?

A: The measurement uncertainty of arrival times can best be verified with comparison of two independent measurements on the same x-ray pulse. Otherwise, the arrival time fluctuations are not decoupled from the PAM accuracy. The

The approach shown in this presentation provides an assessment of the behavior during delay scans and the relative jitter in the machine.

Thanks for the suggestion, as for the uncertainty of arrival times, the arrival times of 2000 FEL pulses have been calculated based on the simulation for abrupt change of transmission. 50 arrival times are recorded at each position of the delay line scan. The uncertainty (17.7fs) is defined as the





drift between the centers of pulses of each delay line position and the fitting line.

In the next step, two independent measurement methods should be added, but only one measurement method can be used during high-repetition-rate online operation.

- Q: Which type of wavefront sensor is better for focal spot measurement? Hartmann or Talbot?

1. A: Hartmann sensors are most popular and used for the optical, VUV, XUV, and soft X-ray domain, while the Talbot method excels towards higher photon energies like in the hard X-ray domain. However, there exists a commercial system based on Hartmann plates by Imagine Optics (FRA).

Hartmann sensors are most popular and used for the optical, VUV, XUV, and soft X-ray domain, while the Talbot method extends towards higher photon energies like in the hard x-ray domain. Due to the acquisition of wavefront from the statistical information of the self-image, the Talbot has higher accuracy wavefront measurement.

- Q: Can the mirror figures be measured online? Are the online measurement results coincide with the offline metrology?

A: Mirror figures are usually not measured online in the installed state (in-situ). However, the mirror surface effects on the beam can be measured in-situ for instance, by imaging and wavefront measurements.

File on Systems enabling FEL experiments (AMO&SES), slide 56:

- Q: New technologies to improve DAQ and control network performance with respect to stability, scalability, and low latency. A: No answer.

A: A two-tier architecture network will be employed. It meets the requirements of stability, scalability, and low latency. The core ethernet switch is one of the high performance switches available in China. The access switch can be replaced if it fails to meet the data transfer requirements, at the same time more powerful access switch is released by vendor, or increasing the access switches.

- Q: How to use proposal ID or user ID as a unique authentication in DAQ, online analysis, offline analysis etc.?

A: We use the domain to manage user accounts. After joining the domain, the user ID in all the DAQ, online analysis, offline analysis, etc. are the same. A directory will be created named with the proposal ID, all the related data will be stored in this directory. This directory will be authorized for access by related users and groups.