

Beamline installation progress and commissioning plan

Speaker: Chaofan Xue

On behalf of the beamline design group

Tuesday, October 20, 2026

- **FEL-II beamline brief**
- **Installation progress**
- **Commissioning plan**

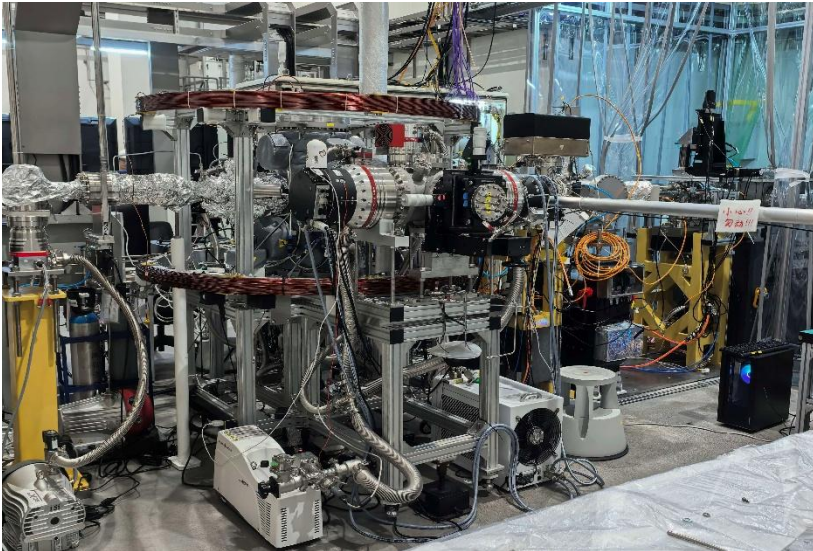
Introduction

The FEL-II beamline will deliver 0.2-3 keV high brightness and high coherence FEL pulses to 3 different endstations:

Atomic, **M**olecular and
Optical Science (AMO)

Soft X-ray **S**cattering
and **S**pectroscopy (SSS)

Spectrometer for
Electronic **S**tructure (SES)

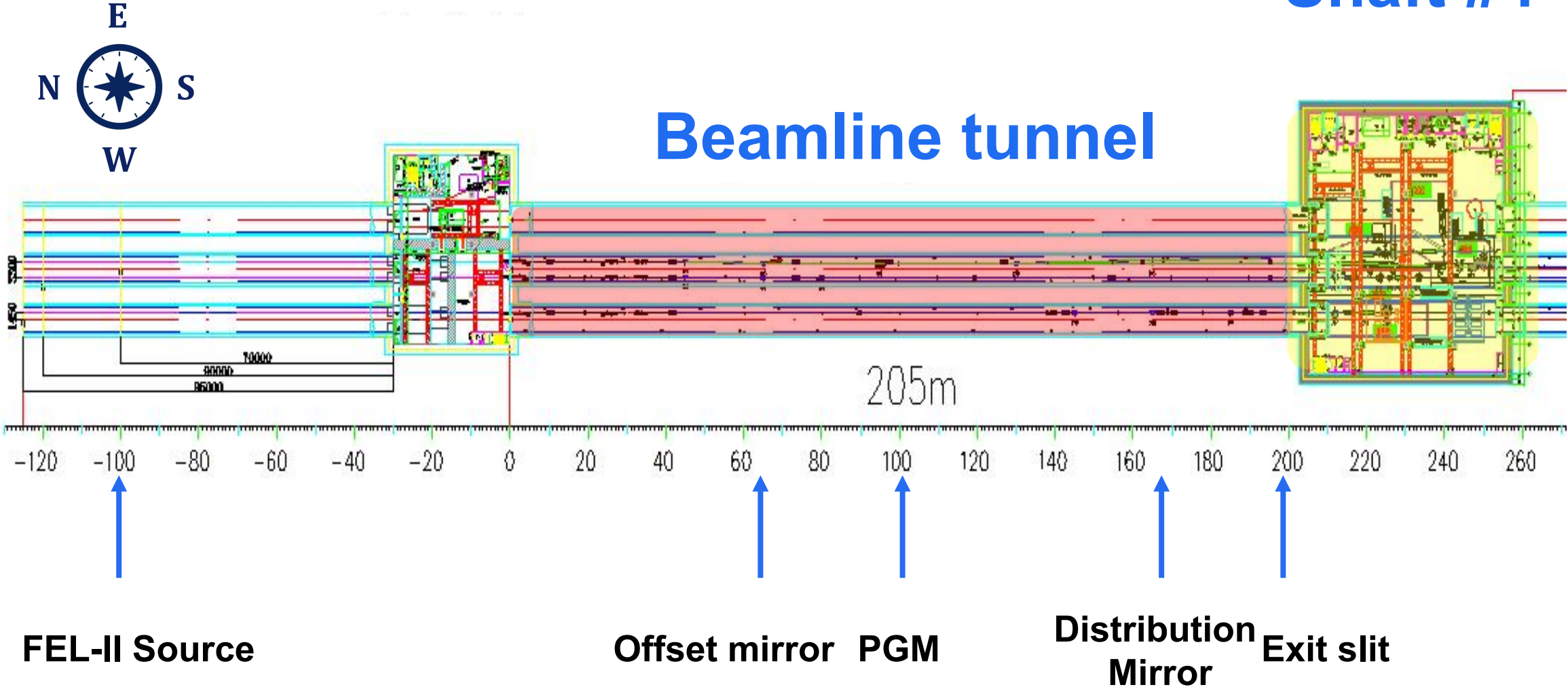


Beamline overall layout: photon transport

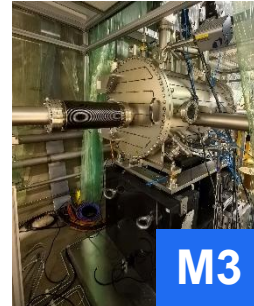
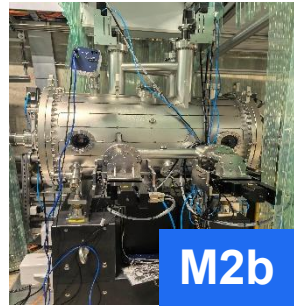
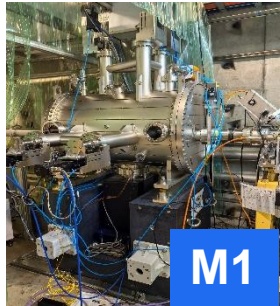
Shaft #3

Shaft #4

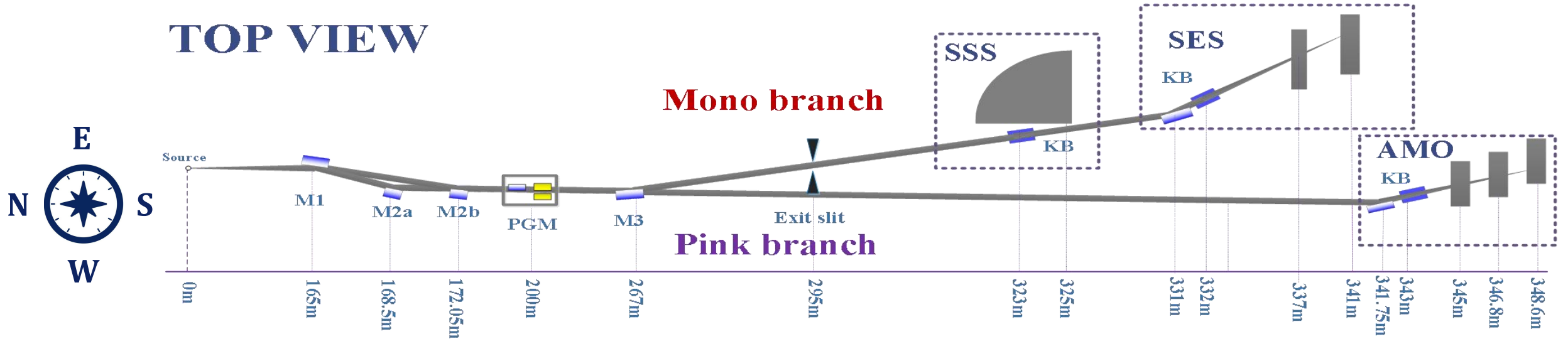
Beamline tunnel



Beamline optical layout



TOP VIEW



Offset mirrors

- 3 plane mirrors divided into two sets for covering whole energy range

PGM

- 2 gratings for different energy resolving power
- 1 ECM for providing ultrafast FEL pulse

Distribution mirror

- 1 plane mirror for reflecting FEL to SES
- 1 ECM for focusing FEL to SSS in horizontal

KB system

- 3 sets for focusing the photon beam at different sample positions

Beamline installation progress

- The installation of FEL-II beamline is started from June 2025 and finished in September 2026.
- Nearly 60 equipment were installed in the beamline.

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Optical chambers

- M1
- M2a
- M2b
- PGM
- M3
- AMO-KB
- SSS-KB
- SES-KB

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Diagnostic tools

- Imager
- GMD&HAMPs
- PES
- Wavefront sensor
- PAM
- SERM
- BLM

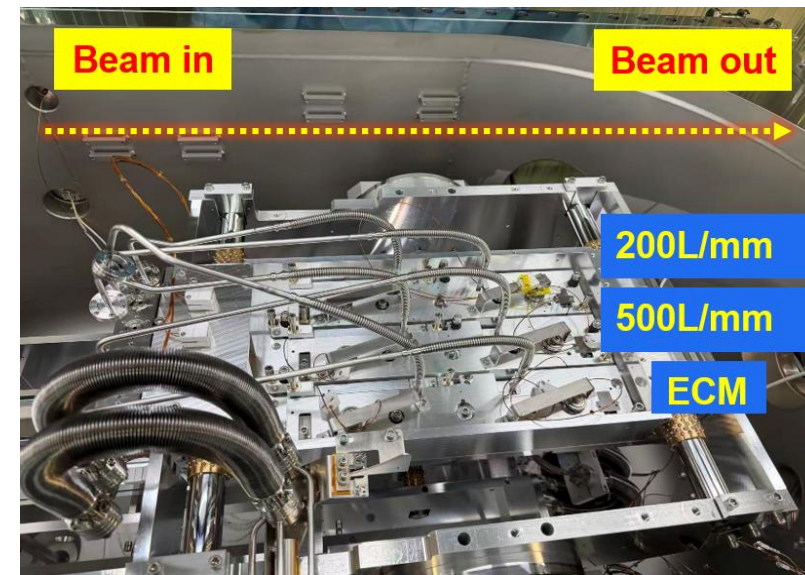
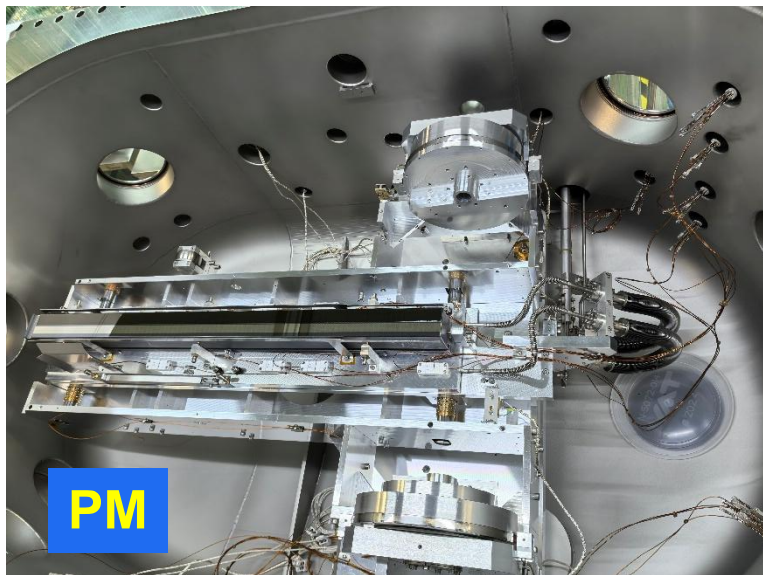
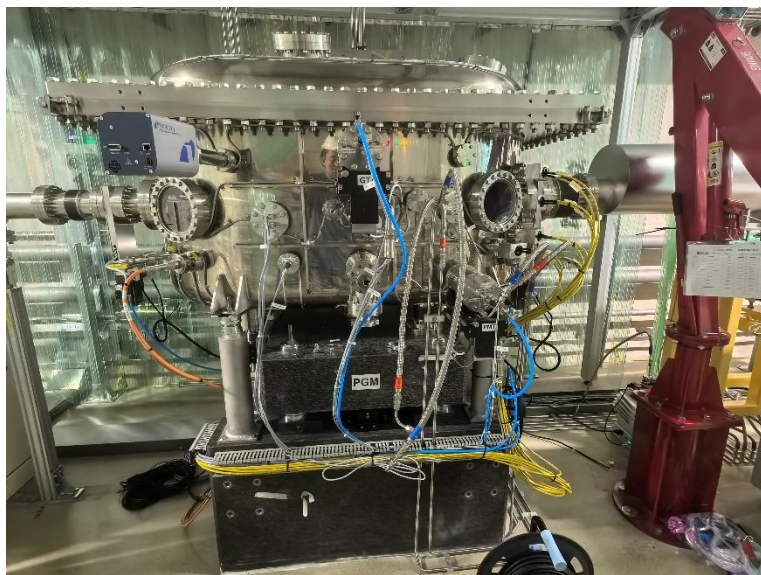
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Other components

- Slit & aperture
- Attenuator (gas+solid)
- Beamstop
- Collimator
- Shutter

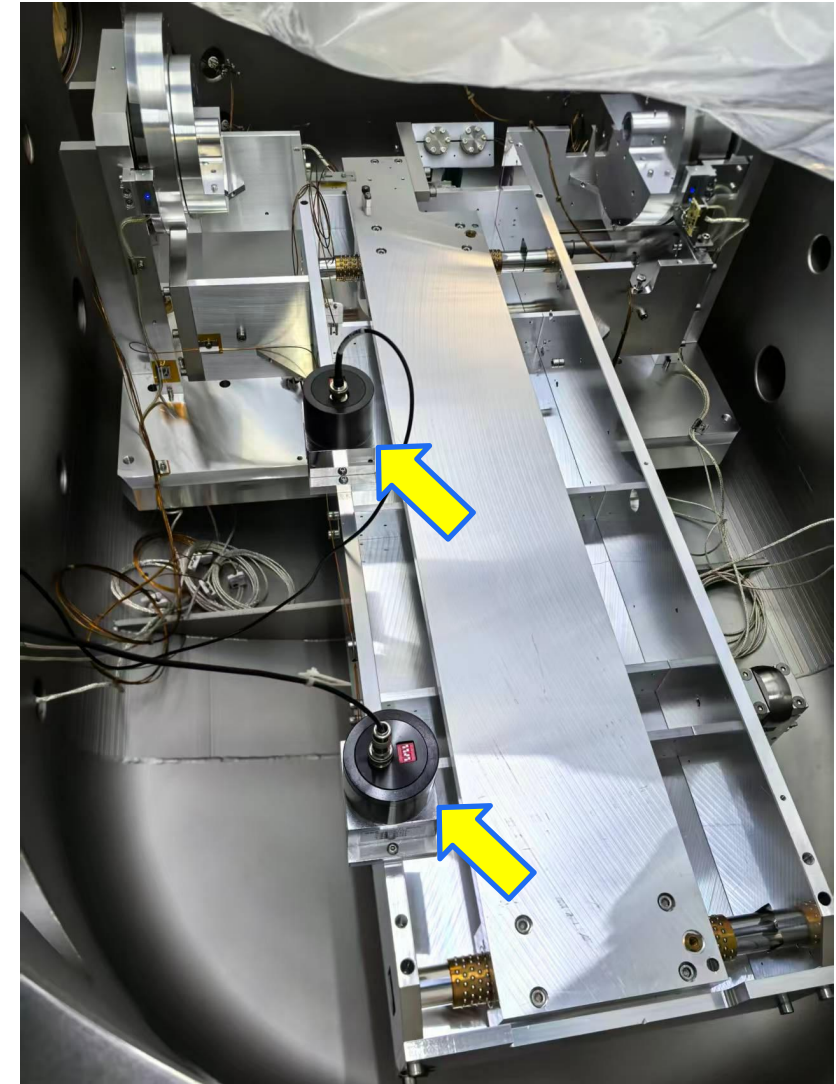
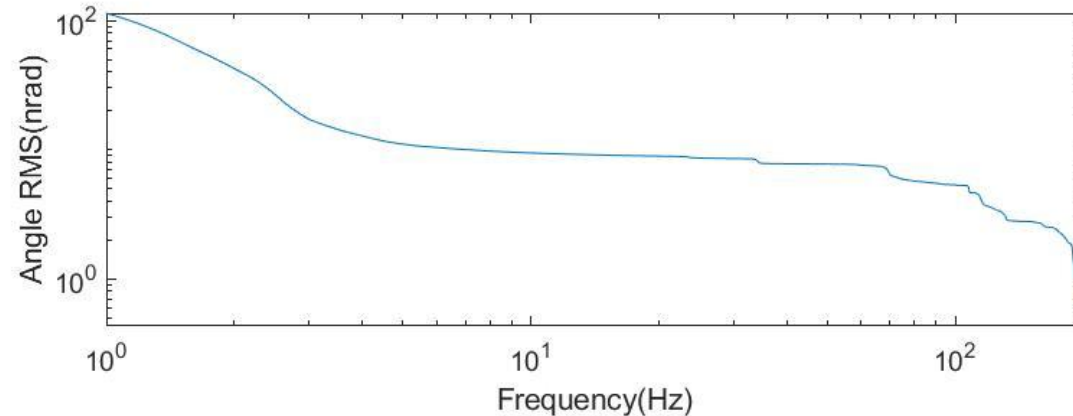
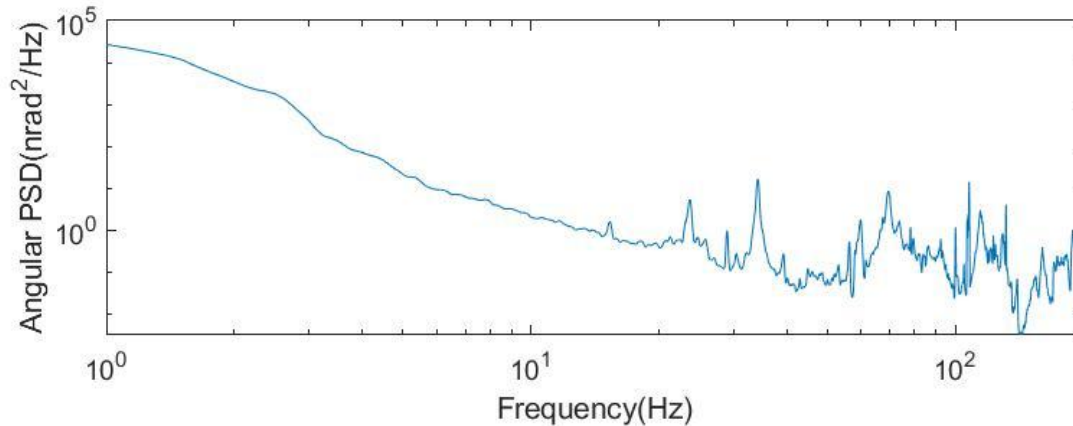
Key components : PGM

- The installation of the PGM is finished in April 2026.
- Water leak was found in the guide vacuum of the grating after baking.
- The FEA result shows that the maximum allowed repetition rate without cooling is **50 kHz** under the condition of **10 μJ** single pulse.

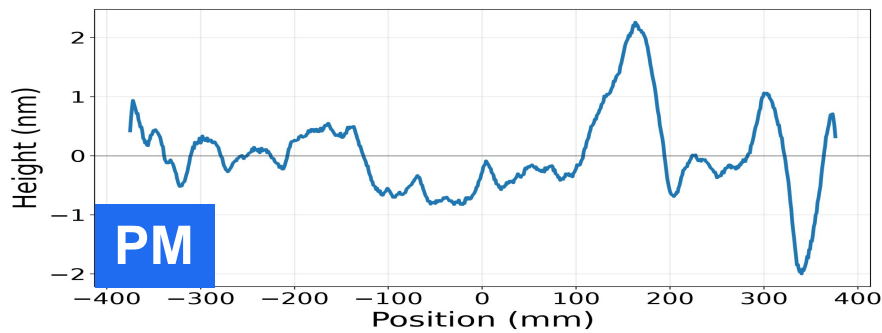
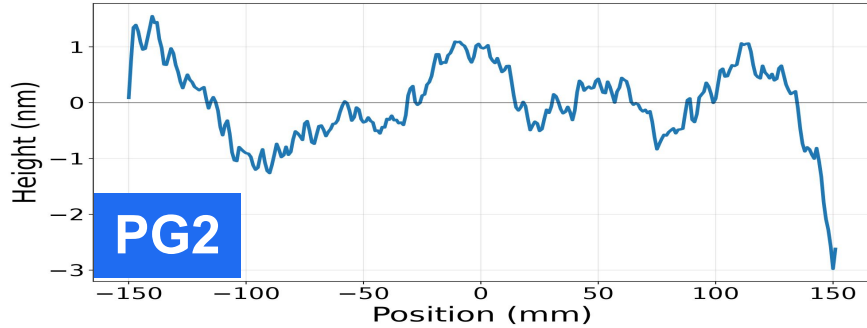
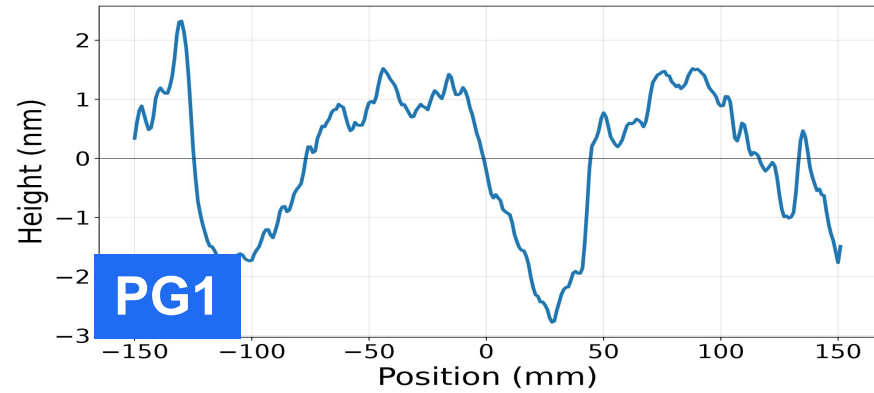


On site vibration measurement: PGM

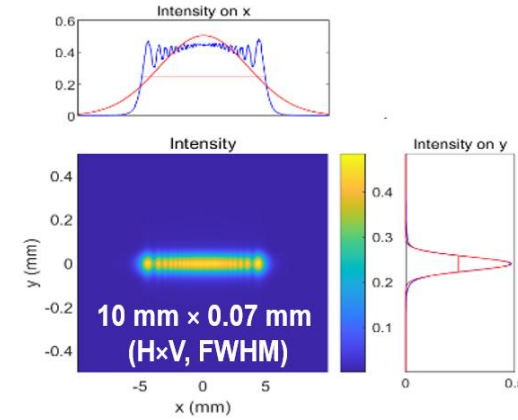
- The absolute vibration is measured using accelerometers.
- Pitch vibration of PM is 10 nrad (10~256Hz) / 114 nrad (1-256Hz)



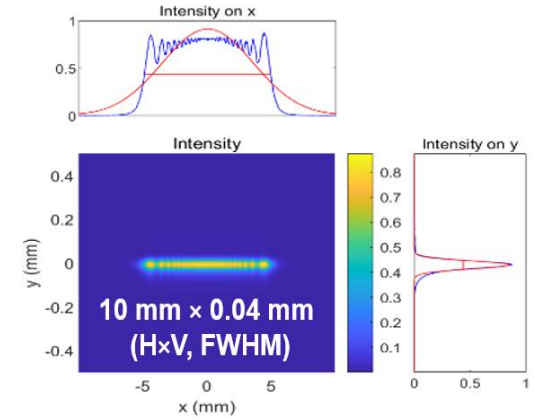
Simulation results: PGM



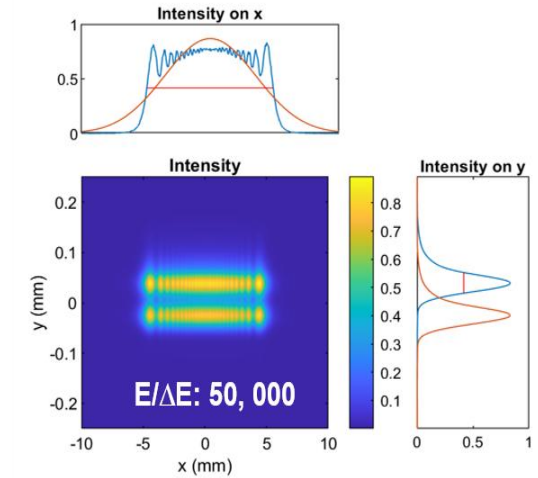
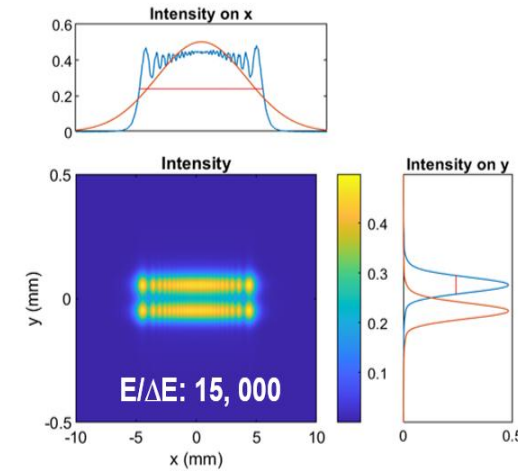
200 l/mm



500 l/mm



Focal spot@exit slit



Energy resolving power

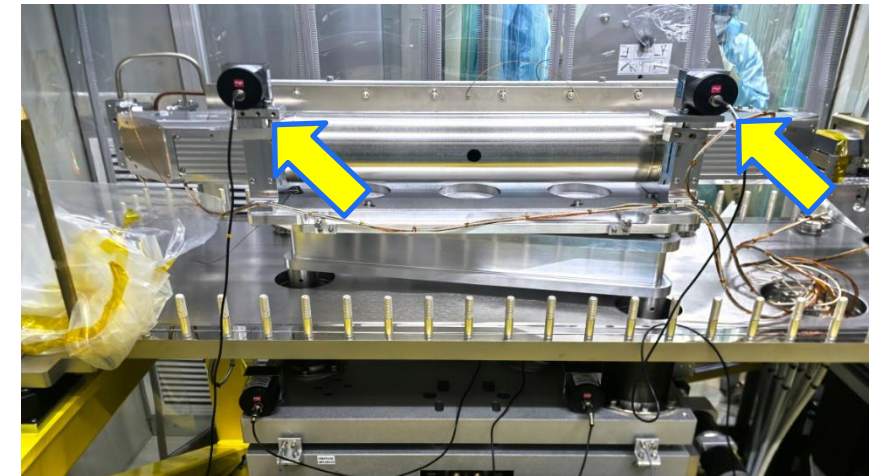
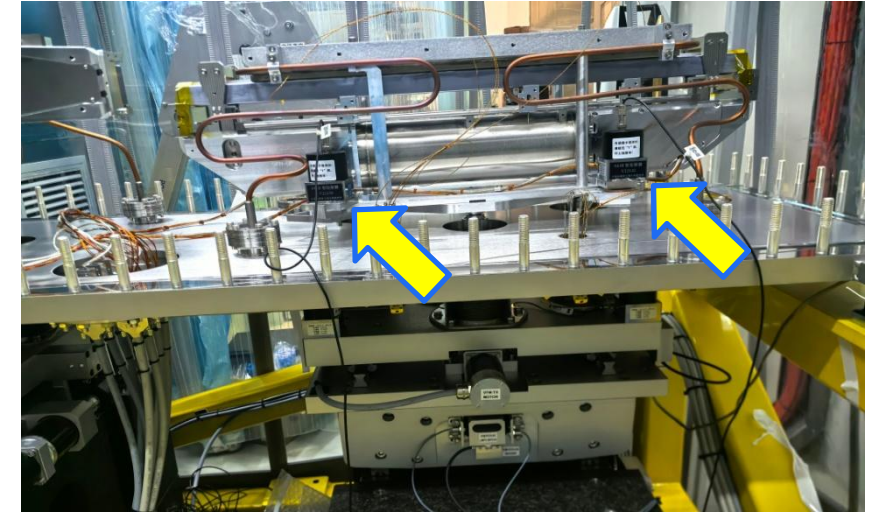
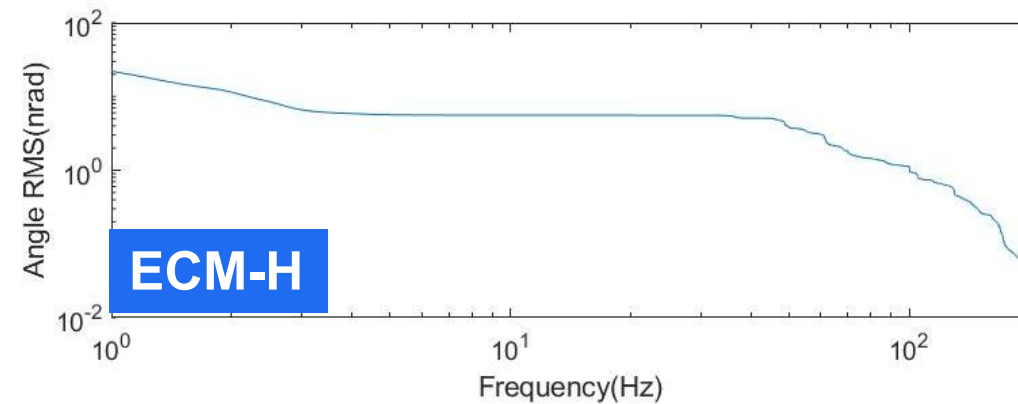
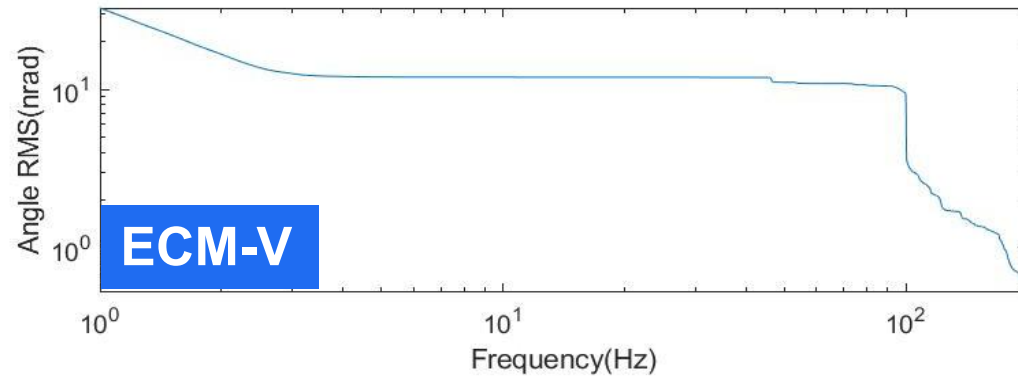
Key components : SES-KB

- The installation of SES-KB system was completed in March 2026 and this was the first KB system to complete installation.
- This KB system is used to provide two focal spots for two sample positions in the SES endstation.

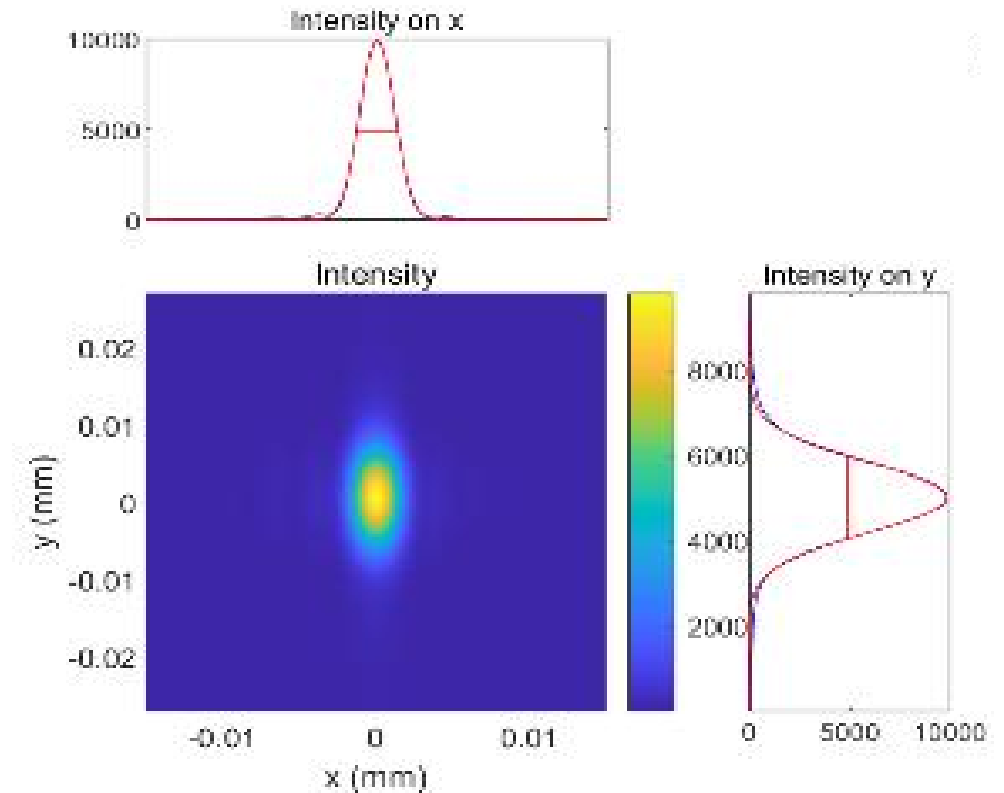
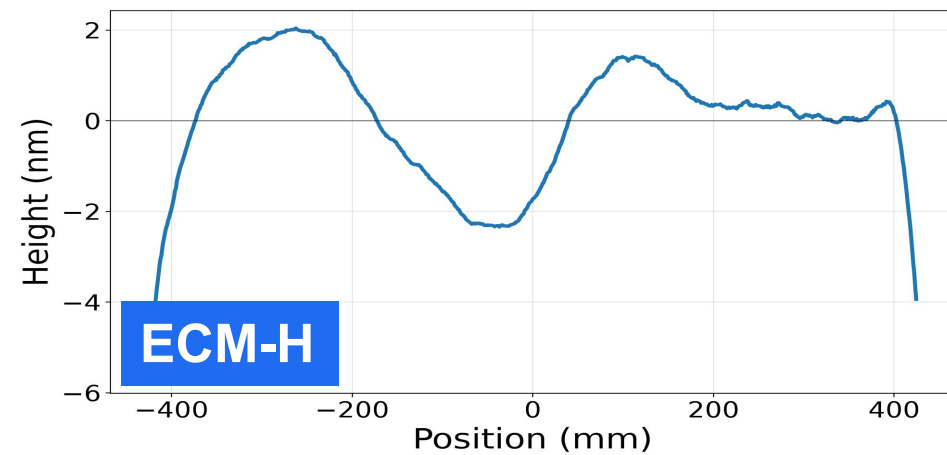
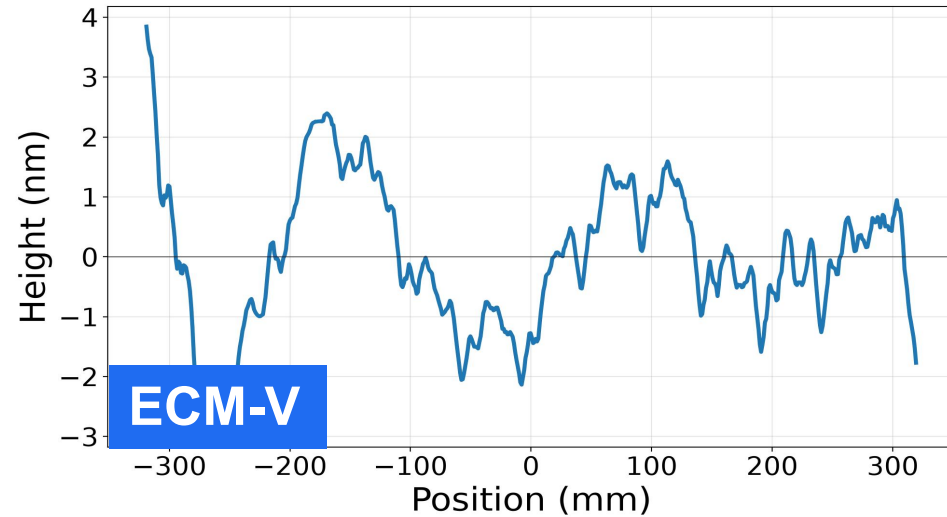


On site vibration measurement: SES-KB

- Pitch vibration of vertical mirror is 32 nrad (1~200Hz)
- Pitch vibration of horizontal mirror is 20 nrad (1~200 Hz)



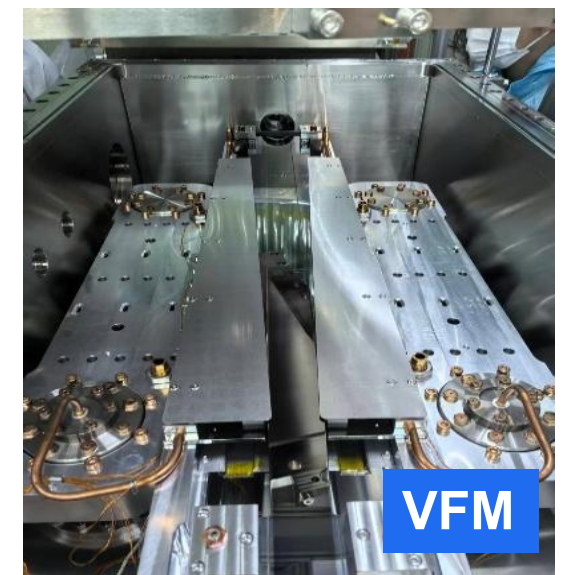
Simulation results: SES-KB



Simulated focal: $3.0\text{ }\mu\text{m} \times 10.0\text{ }\mu\text{m}$ @ F1

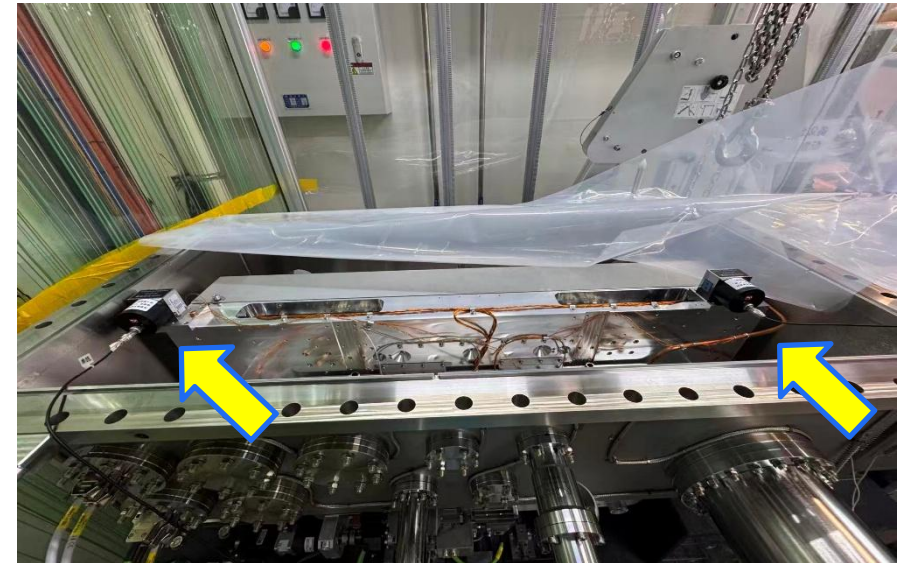
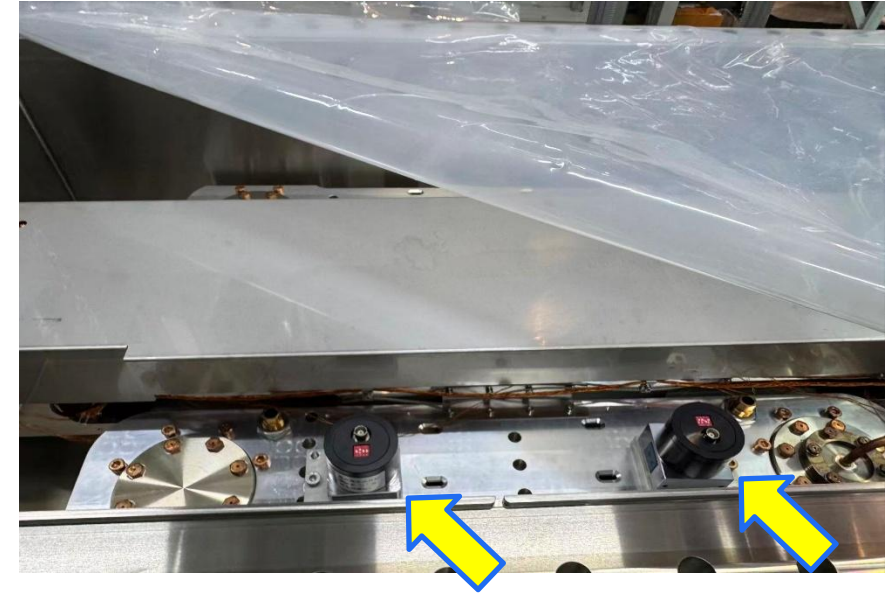
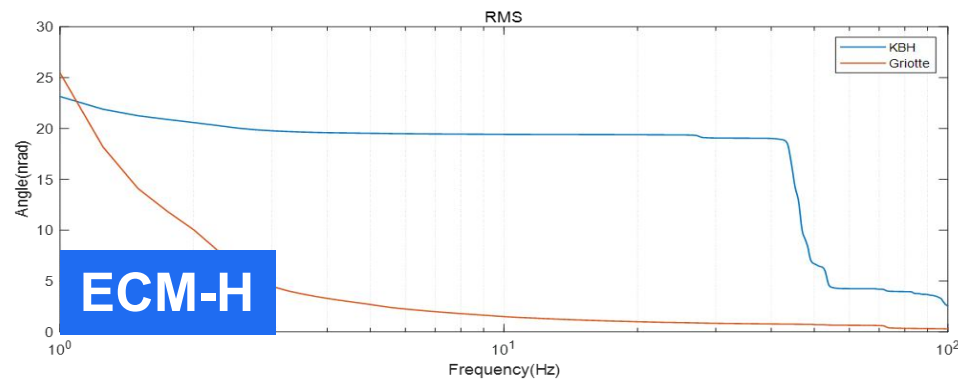
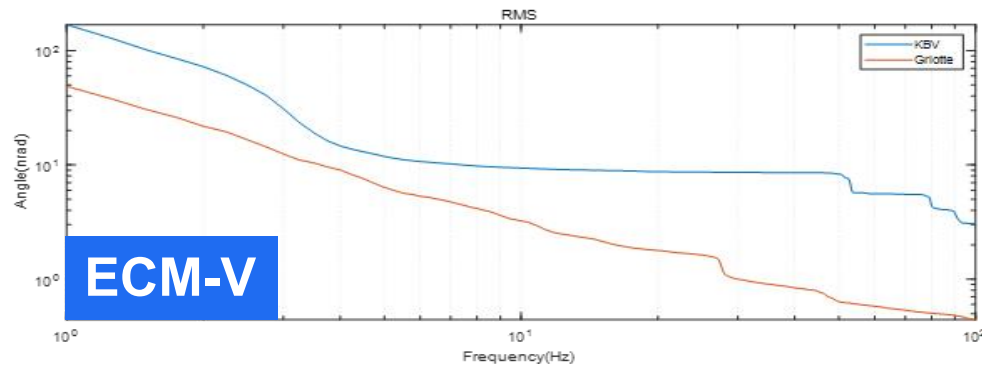
Key components : AMO-KB

- Due to the delay of the mirrors, the AMO- KB system was the last one to complete installation.
- This KB system is used to provide the focused spots for three sample positions in the AMO endstation.

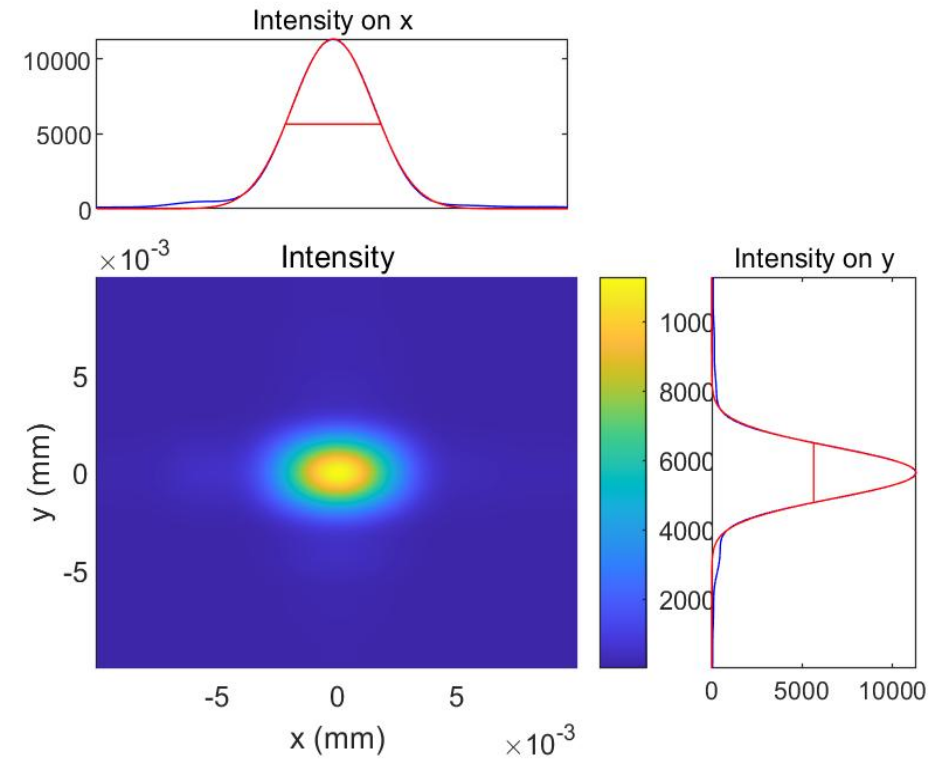
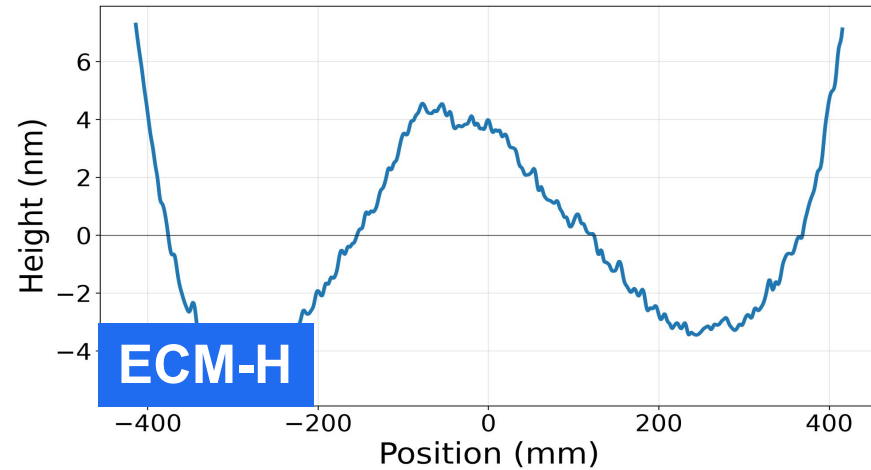
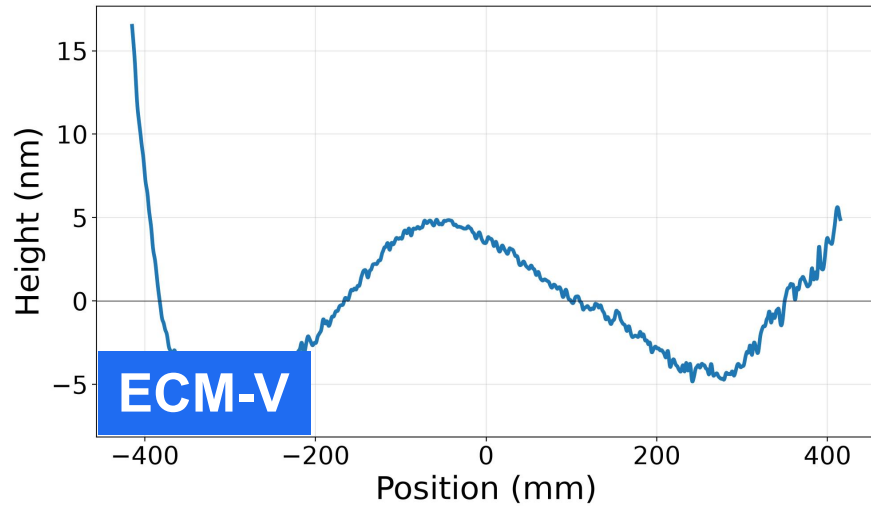


On site vibration measurement: AMO-KB

- Pitch vibration of vertical mirror is 150 nrad (1~100Hz)
- Pitch vibration of horizontal mirror is 23 nrad (1~100 Hz)



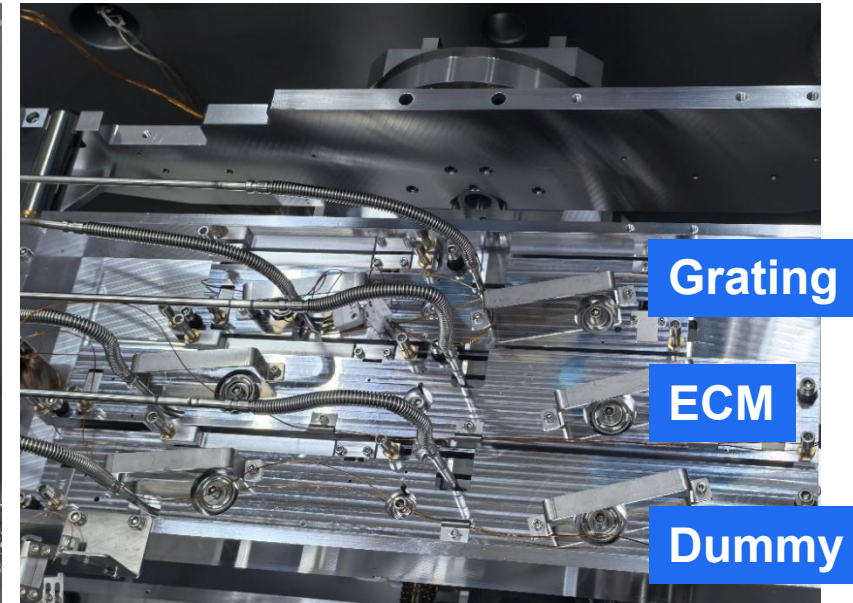
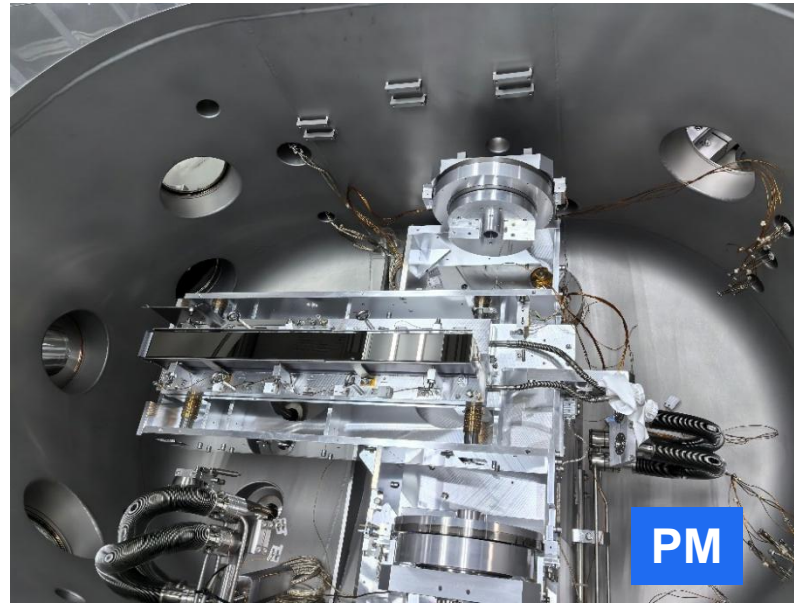
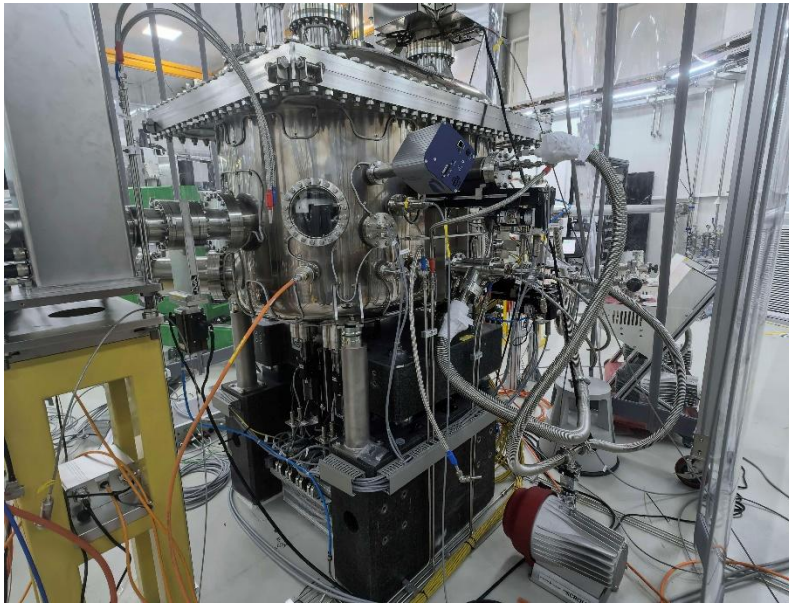
Simulation results: AMO-KB



Simulated focal: $4.0\ \mu\text{m} \times 3.0\ \mu\text{m}$ @ F2

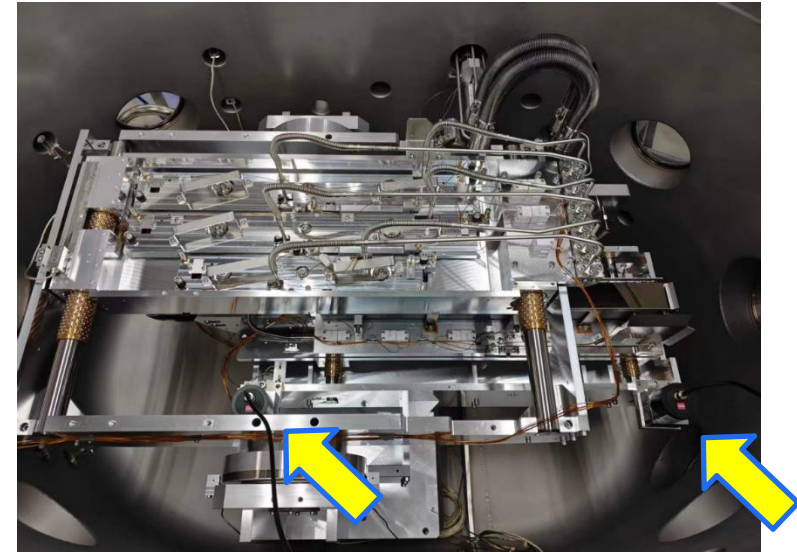
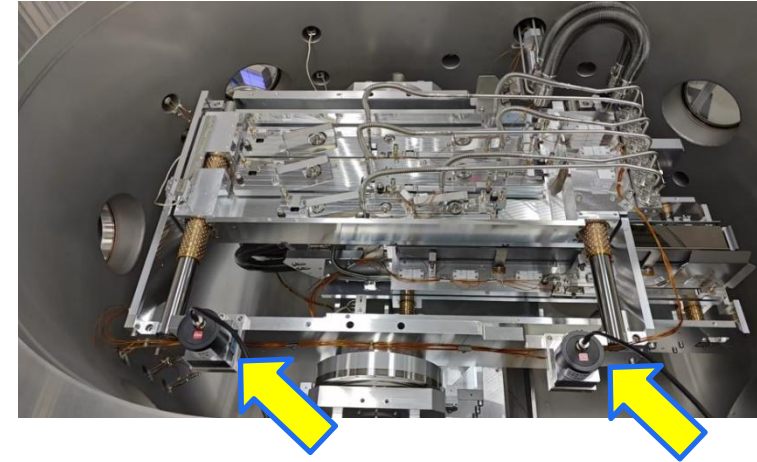
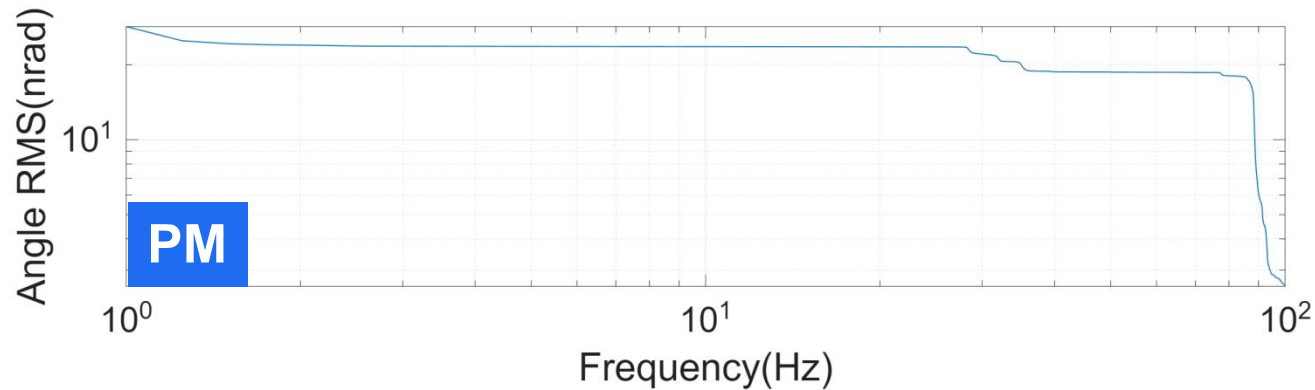
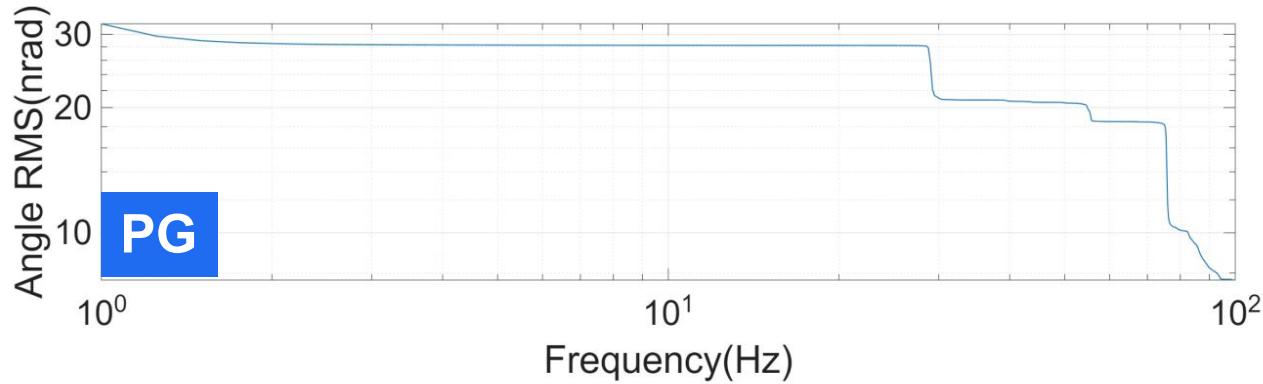
Key components : SSS-KB

- The installation of SSS-KB system has also been finished now.
- The optics are moved out of the beam path to let the photon beam pass through in the 1st round commissioning.



On site vibration measurement: SSS-KB

- Pitch vibration of grating is 32 nrad (1~100Hz)
- Pitch vibration of PM is 29 nrad (1~100 Hz)



Commissioning plan

Commissioning schedule

- The first-round commissioning of FEL-II beamline will begin on 15th November
- A total commissioning period of 43 days is scheduled for beamline, endstation and diagnostic tools

Nov.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
	Accelerator														Arrive at AMO			Arrive at SES			GMD		GAT			AMO-KB@F2				
Dce.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27			
	AMO-KB@F1			PE S	PAM@AMO		AMO experiment					SES-KB@F1				SES experiment		Energy resolving power				BLM			PAM@SES					

25 days for beamline

11 days for diagnostic tools

7 days for endstation

Commissioning goal

- Main goal: To deliver the photon beam to AMO and SES for preliminary experiment
- Secondary goal: to test some beamline performance such as energy resolving power

Source parameters in the 1st stage (driven by branch linac accelerator)

FEL mode	SASE
e-Beam parameters	4.0 GeV、 50pC、 > 500A、 0.5mm*mrad 0.015% sliced energy spread
Photon energy (eV)	244
Pulse length (fs, FWHM)	< 50
Repetition rate (Hz)	10
Pulse energy (μJ)	> 10
Size (μm, FWHM)	200
Divergence (μrad, FWHM)	50

■ FEL Spot by imager:

- Spot size and divergence
- Position

■ FEL pulse energy and gain curve

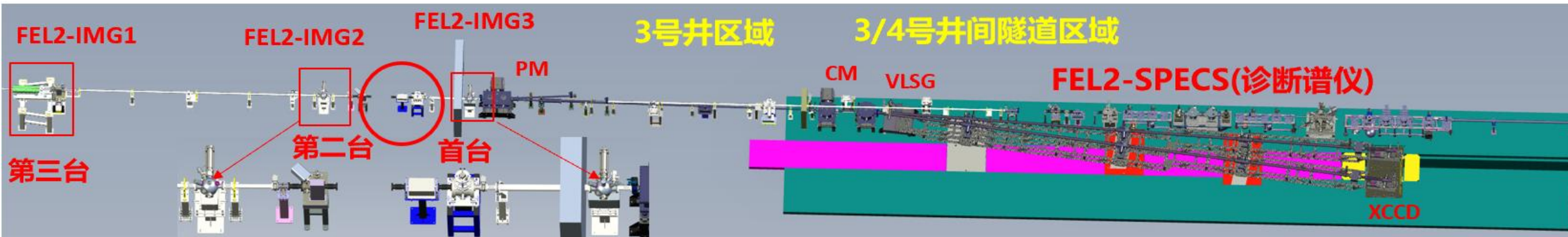
- Photo-diode
- XGMD located in beamline
- 3 Imagers

■ Photon energy:

- Spectrum using spectrometer, resolution ~ 20000 @0.14-3keV

■ pulse duration:

- TDS, resolution $\sim 1\text{fs}$
- THz-Streaking (standby)



Courtesy of Dr. Tao Liu from Accelerator Division

Commissioning plan

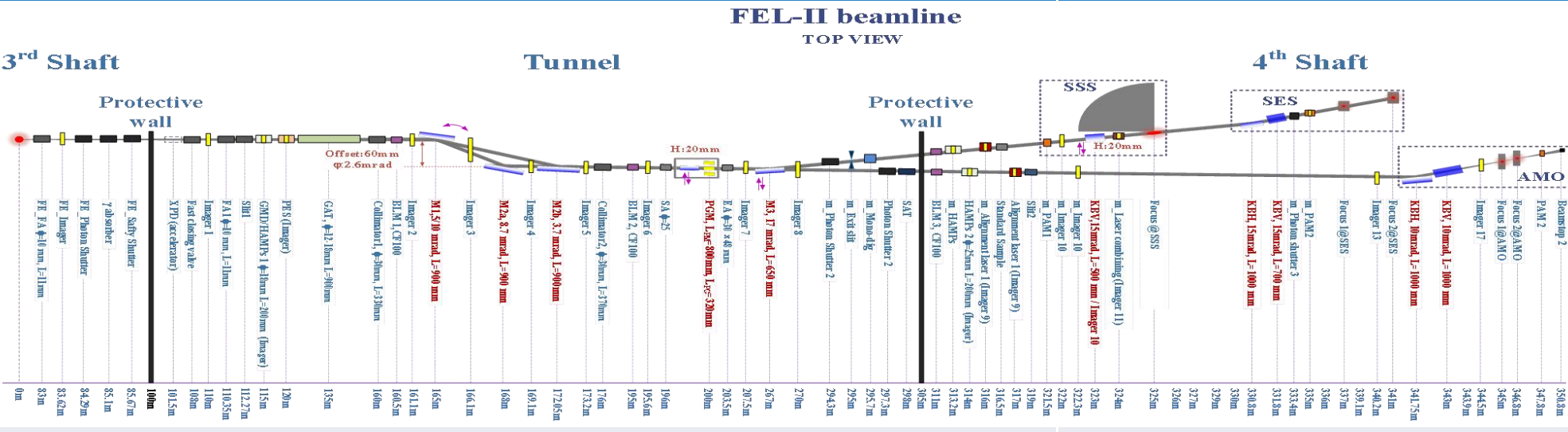


Beamline (25 days)

Front-end	2 days	The beam passes through FE_Imager, Imager1, GMD/Hamps, and GAT to reach Imager2	Spot can be observed on Imager2
M1/M2a+ AMO-KB	1 day	The beam reaches AMO-KB through M1, M2a. The PGM will be moved out of the beam path here.	Spot can be observed at AMO
PGM(ECM) + M3	2 days	The beam passes through the PGM and M3. The ECM in the PGM will be moved in the beam path.	Spot can be observed on Imager 7/8
SES-KB	1 days	The beam reaches SES-KB	Spot can be observed at SES
AMO-KB	8 days	Commissioning of AMO-KB	Spot size <50 μm @ F2 & F1
SES-KB	4 days	Commissioning of SES-KB	Spot size <50 μm @ F1
GAT	3 days	Test the proportional relationship between gas pressure and attenuation factor.	
Energy resolution	4 days	Measure the energy resolving power of the monochromator at the Ar edge.	

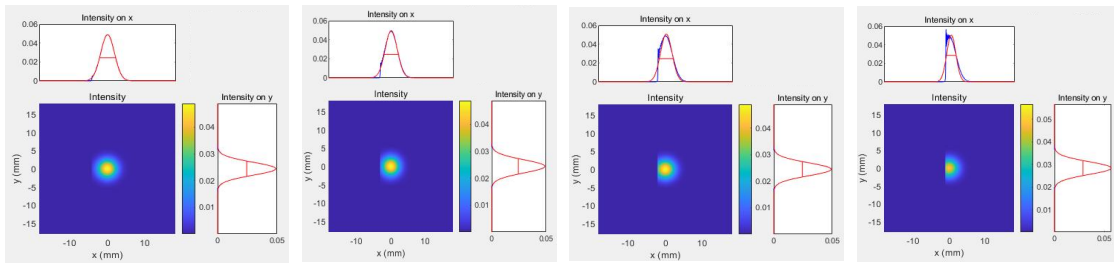
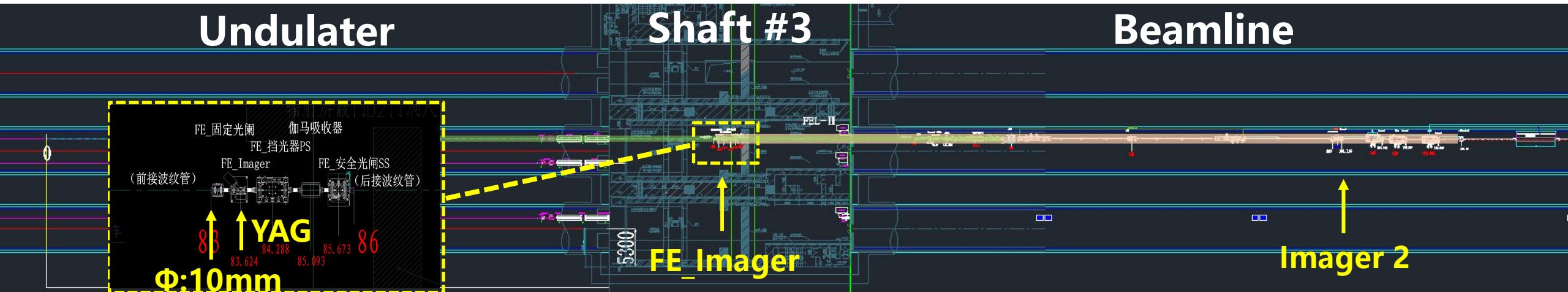
Diagnostic Equipment

Imager	11 days
GMD / HAMPs	
PES	
BLM	
Endstation (7 days)	
AMO	5 days
SES	2 day



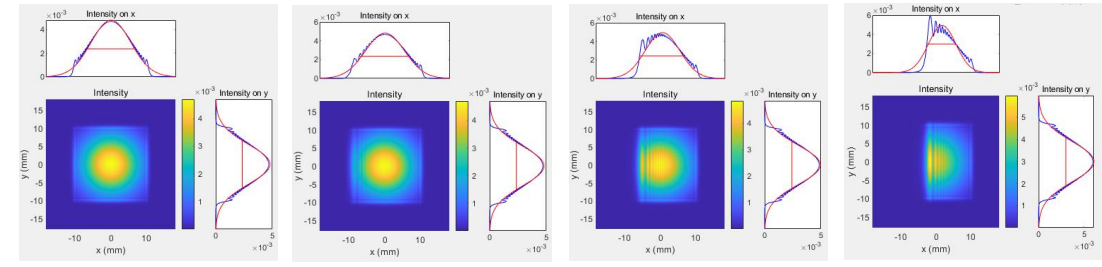
Optical axis alignment

- The alignment of the accelerator and beamline was carried out separately.
- The accelerator section has been extended to ensure accurate handover of the two alignment surveys by creating a 100 m overlapping region.
- Photon beam will be optimized by accelerator with the center of **FE_Imager** as a reference.



Offset to FE_FA: 1mm 2mm 3mm 4mm

Simulated beam spot @ **FE_Imager**



1mm 2mm 3mm 4mm

Simulated beam spot @ **Imager 2**

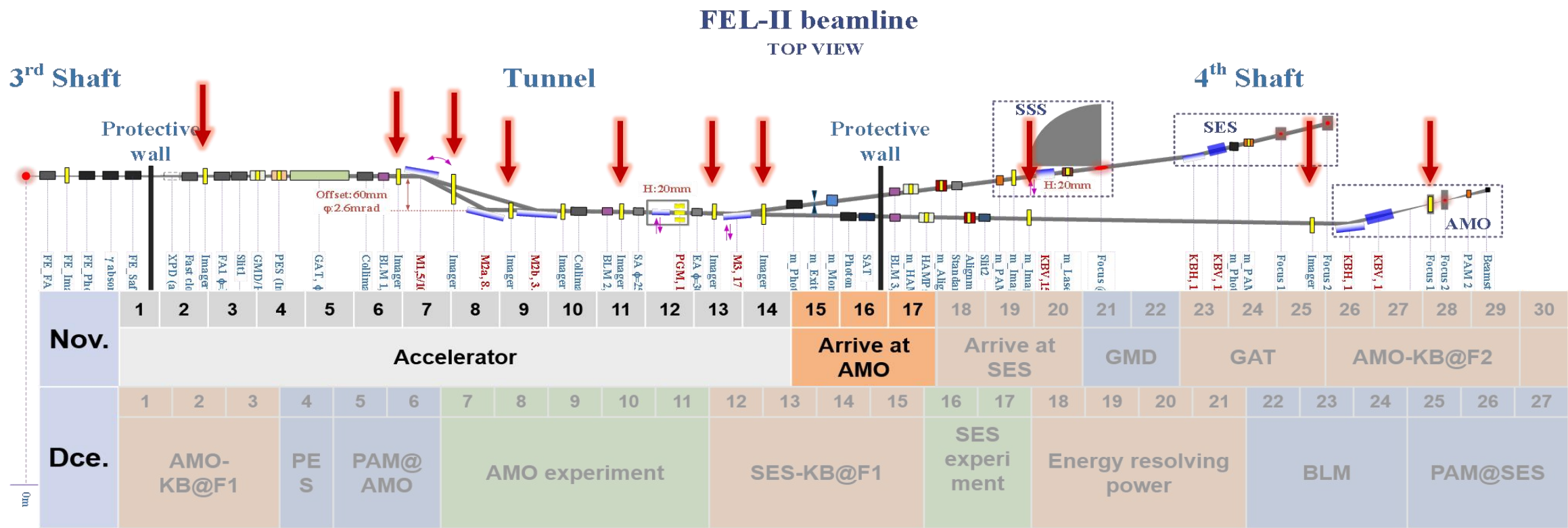
Commissioning difficulties

- The accelerator is required to have an ability to move the photon beam by ± 0.5 spot size.
- The minimum aperture before M1 is 78 μ rad at the GAT (the divergence at 244eV is expected to 50 μ rad).

Device	Position (from source)	Aperture	Length	Observation
FE_Fixed aperture				FE_Imager
FE_Imager				
Photon shutter				Out of beam path
γ -absorber				Imager 1
Safety shutter				Out of beam path
Fast closing valve				Out of beam path
Imager 1				Out of beam path
Fixed aperture 1				GMD/ HAMPs1
Slit 1				Imager in HAMPs
GMD/HAMPs1				Imager in HAMPs
PES				Imager in PES
GAT				Imager 2
collimator 1				Imager 2
BLM 1				Imager 2
Imager 2				Out of beam path
M1				

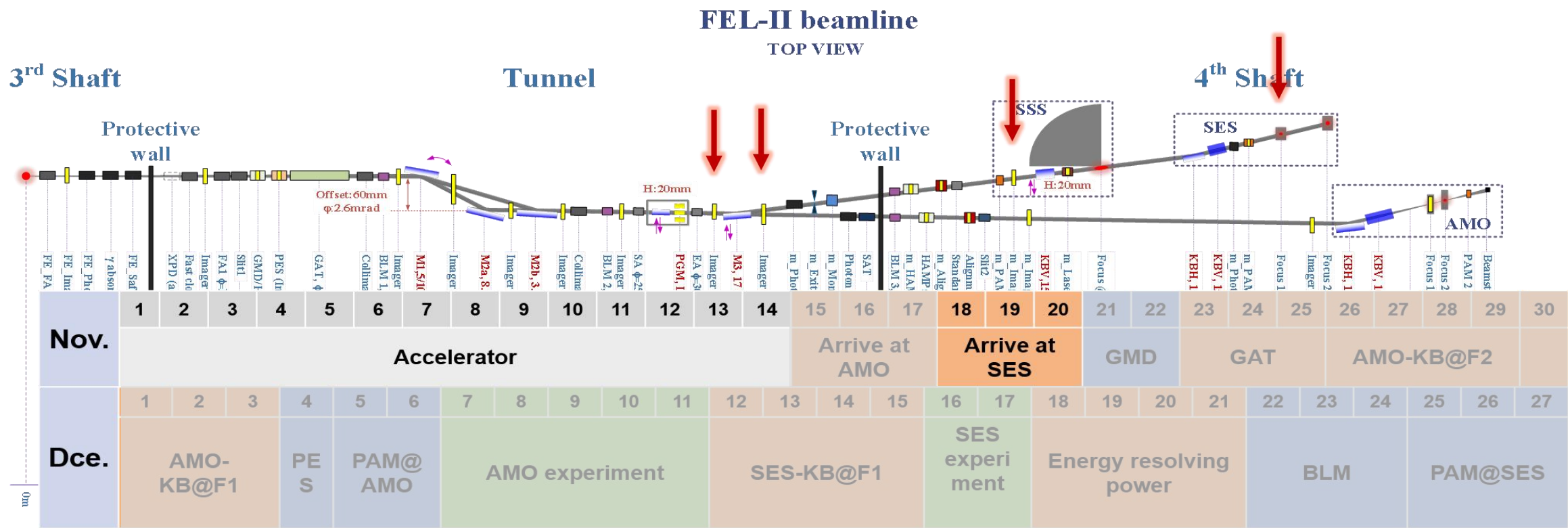
Day by day plan: arrive at AMO

	Goal	Work
Day 1	FEL beam arrive at the AMO endstation	- FEL beam can be observed on FE_Imager. - FEL beam pass through the front-end and can be observed on Imager1
Day 2		- FEL beam pass through GMD, GAT and can be observed on Imager2 - FEL beam pass through M1 and M2a and can be observed on Imager3 / 4
Day 3		- FEL beam can be observed sequentially on Imager 6 / 7 / 8 / 10 / 13 - FEL beam pass through the AMO-KB and can be observed on the Focus Imager



Day by day plan: arrive at SES

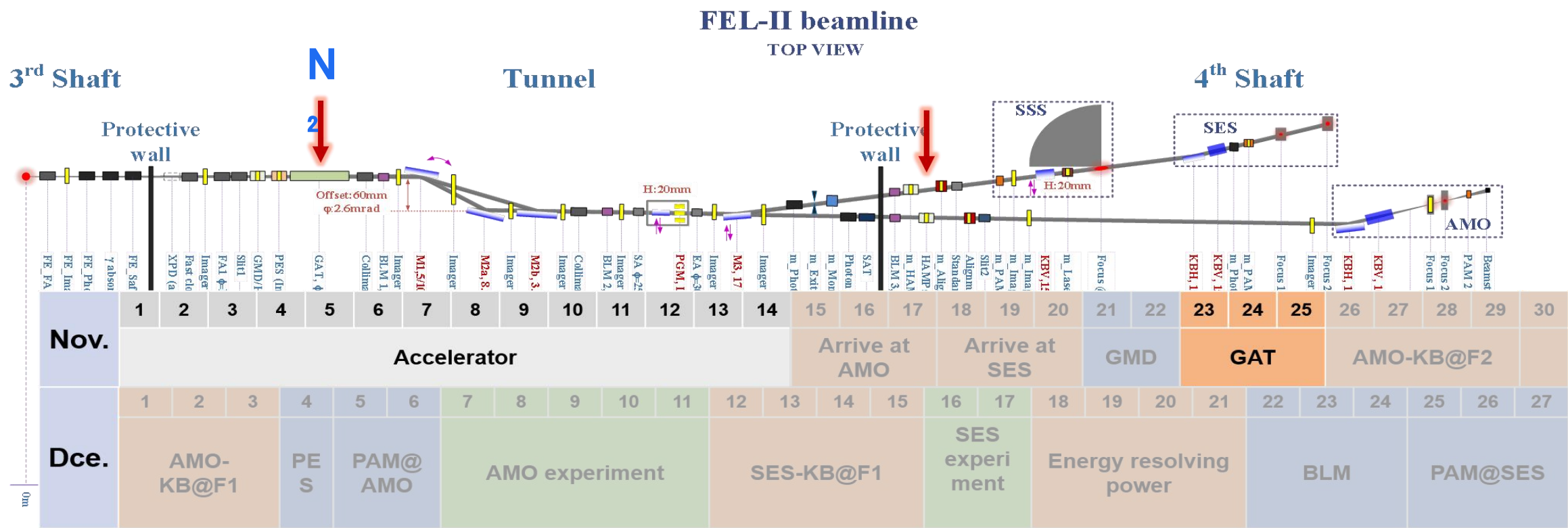
	Goal	Work
Day 1	FEL beam arrive at the SES endstation	• FEL beam pass through the PGM and can be observed on Imager 7
Day 2		• FEL beam pass through M3 and can be observed on Imager 8 / m_Imager 10
Day 3		• FEL beam pass through the SES-KB and can be observed on YAG screen in endstation



Day by day plan: GAT

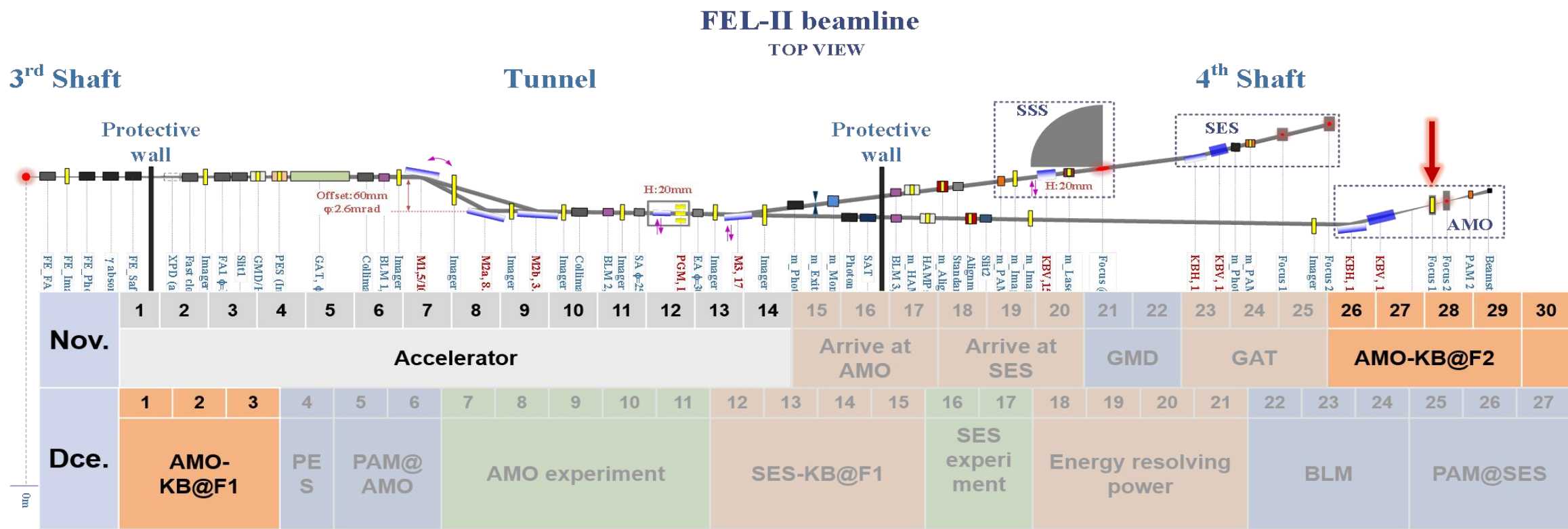
	Goal	Work
Day 1 - Day 3	Get the proportional relationship between the gas pressure and attenuation coefficient	N_2 is selected as the working gas inside the GAT - Measure the beam intensity at various pressures using the GMD on pink branch to get attenuation coefficient

Commissioning of the GMD will be completed before this step



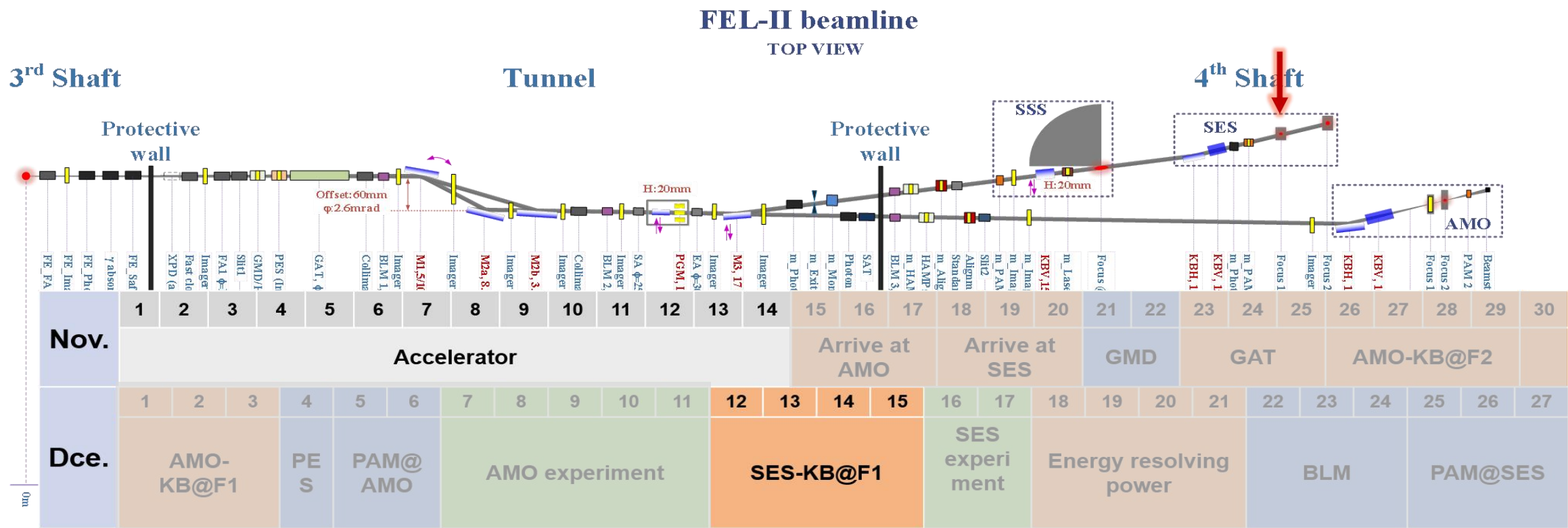
Day by day plan: AMO-KB

	Goal	Work
Day 1 - Day 4	Commissioning of the AMO-KB	The focal is better than 50 μm at the 2nd focus
Day 5 - Day 8		The focal is better than 50 μm at the 1st focus



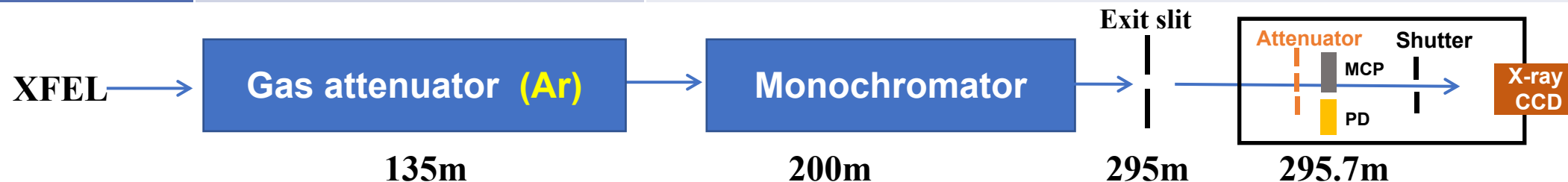
Day by day plan: SES-KB

	Goal	Work
Day 1 - Day 4	Commissioning of the SES-KB	The focal is better than 50 μm at the 1st focus



Day by day plan: Energy resolving power

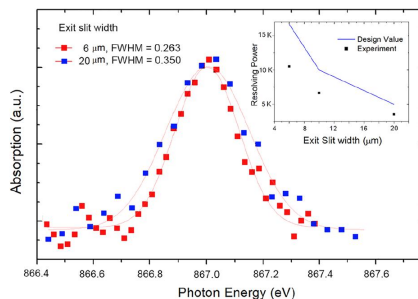
	Goal	Work
Day 1 - Day 2	Measure the energy resolving power of the PGM at the Ar edge	- Fill the gas attenuator with a certain amount of Ar gas - Close the exit slit and measure the transmission spectrum via energy scan
Day 3 - Day 4		- Fill the gas attenuator with a certain amount of Ar gas - Open the exit slit and record the transmission spectrum by CMOS



Route 1:

transmission spectrum via energy scan measured by PAL-XFEL

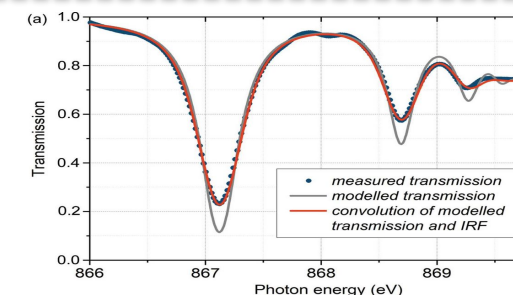
S.H. Park et al., Rev. Sci.Instrum..2018. 89(5):055105



Route 2:

Transmission spectrum measured by EuXFEL

N. Gerasimova et al., J. SynchrotronRad., 2022, 29



Nov.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
	Accelerator														Arrive at AMO		Arrive at SES		GMD		GAT		AMO-KB@F2							
Dce.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27			
	AMO-KB@F1			PE S	PAM@AMO		AMO experiment					SES-KB@F1				SES experient		Energy resolving power				BLM			PAM@SES					

- After 15 months of installation, the beamline installation was completed in September and the beamline is ready for commissioning now.
- The 1st round commissioning of FEL-II beamline will be started on 15th Nov.
- The beamline will take 25 days to **deliver the beam to SES and AMO endstations** and get a spot size better than **50 μm at the sample position** in the 1st round commissioning.



Thank you for your attention!

