



FEL-II Endstation Overview

Recent Progress & Commissioning Plan

SHINE TAC Meeting, Oct 20, 2026

Yulin Chen
On behalf of the FEL-II Team



FEL-II Overall progress: Beamline & Auxiliary Support



FEL-II Beamline: Construction Progress and Commissioning Plan

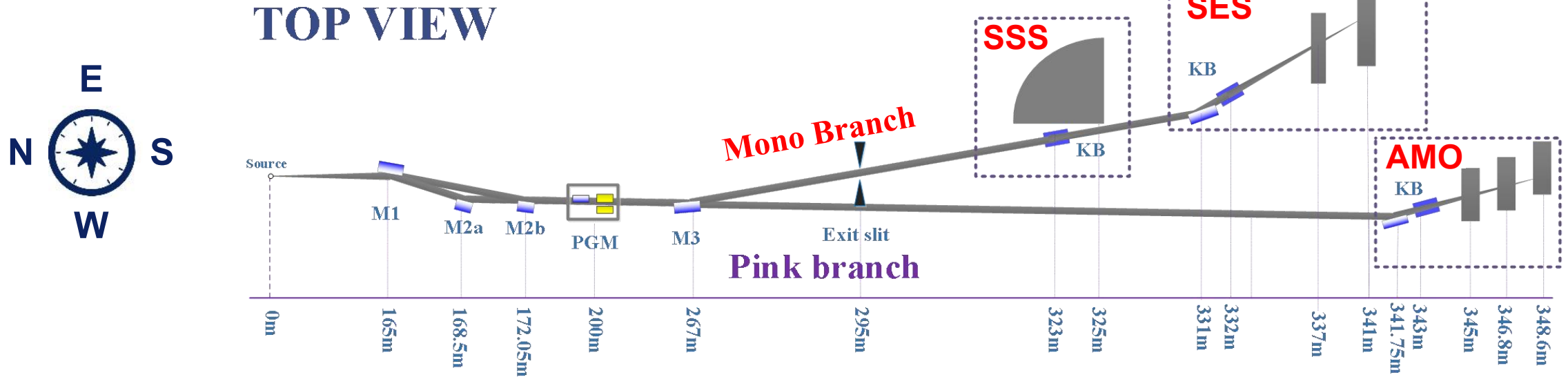
Yajun Tong



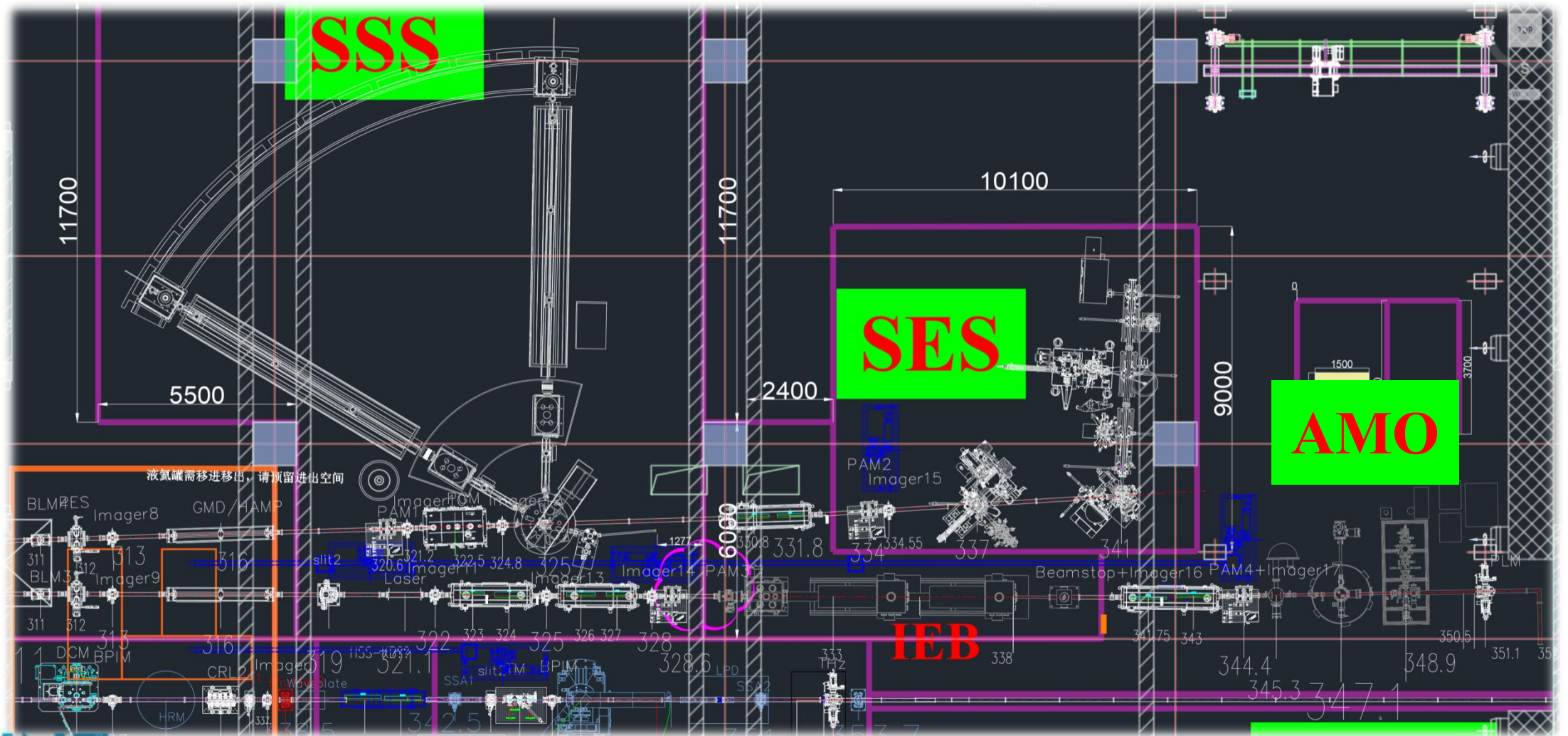
General Experimental Technologies for SHINE FEL-II:
Commissioning Readiness and System Integration Progress

Ping Huai

FEL-II Endstation Layout

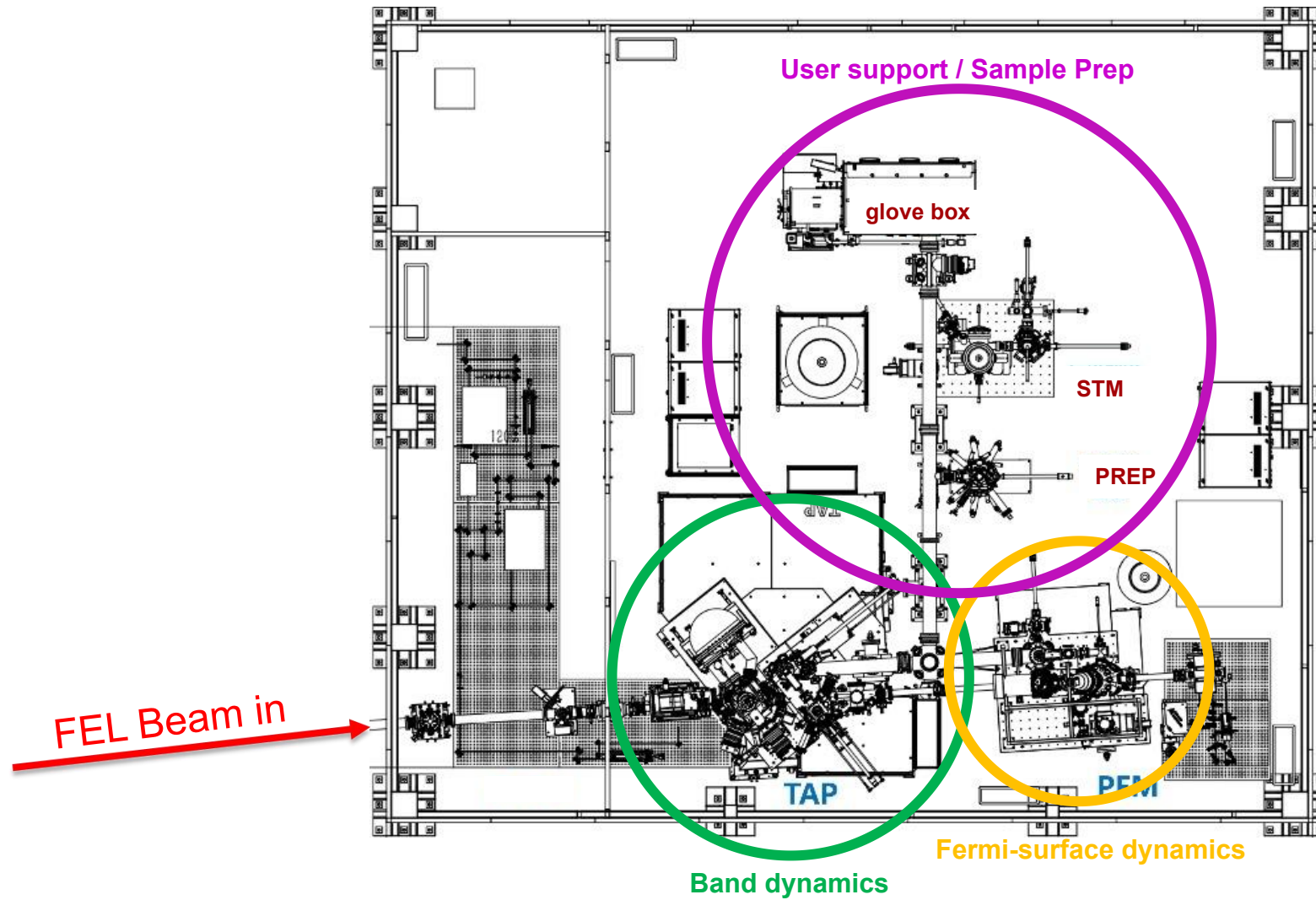


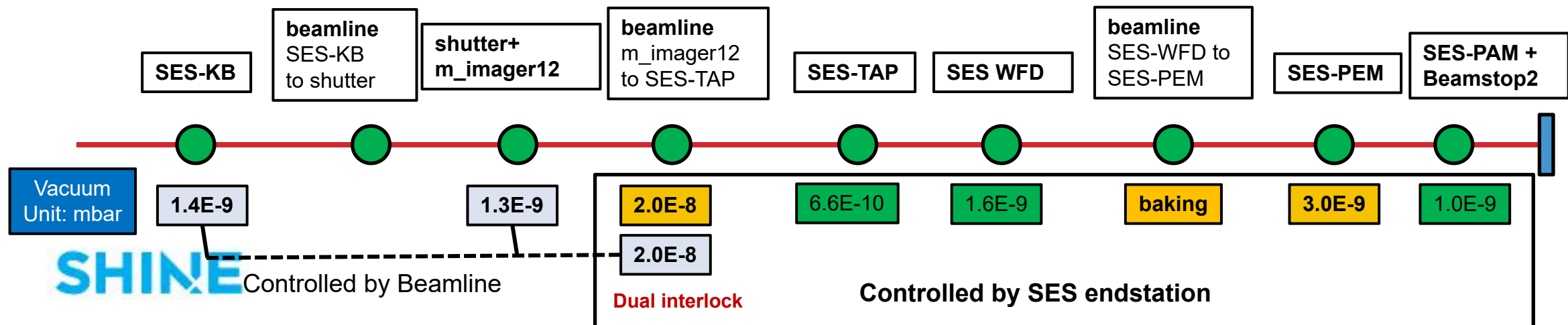
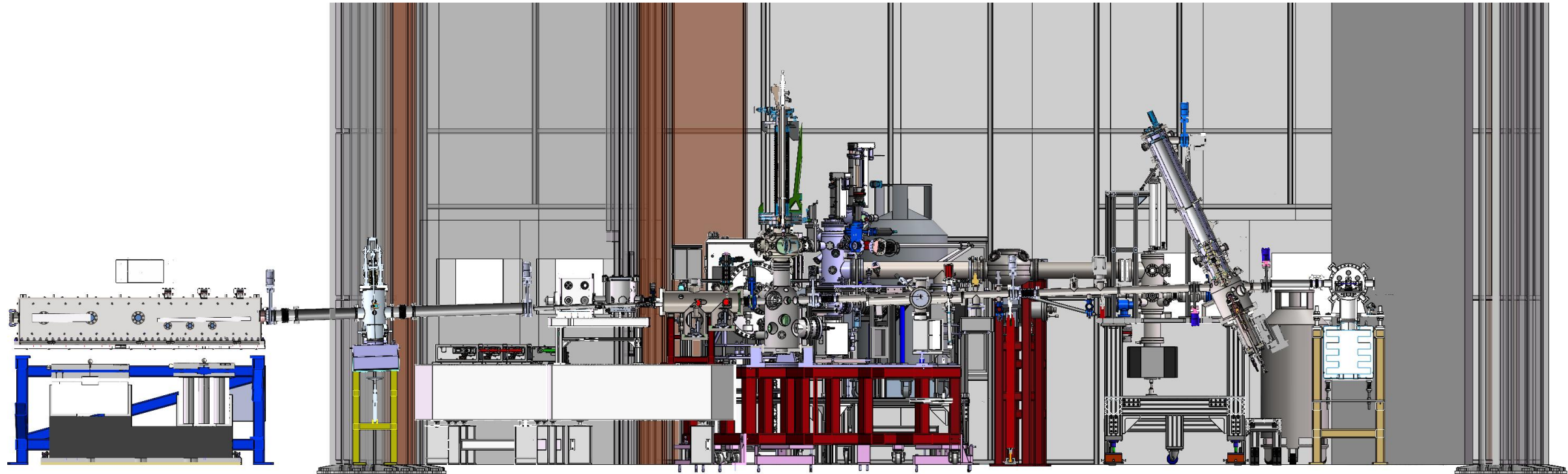
FEL-II Endstation Floor Plan



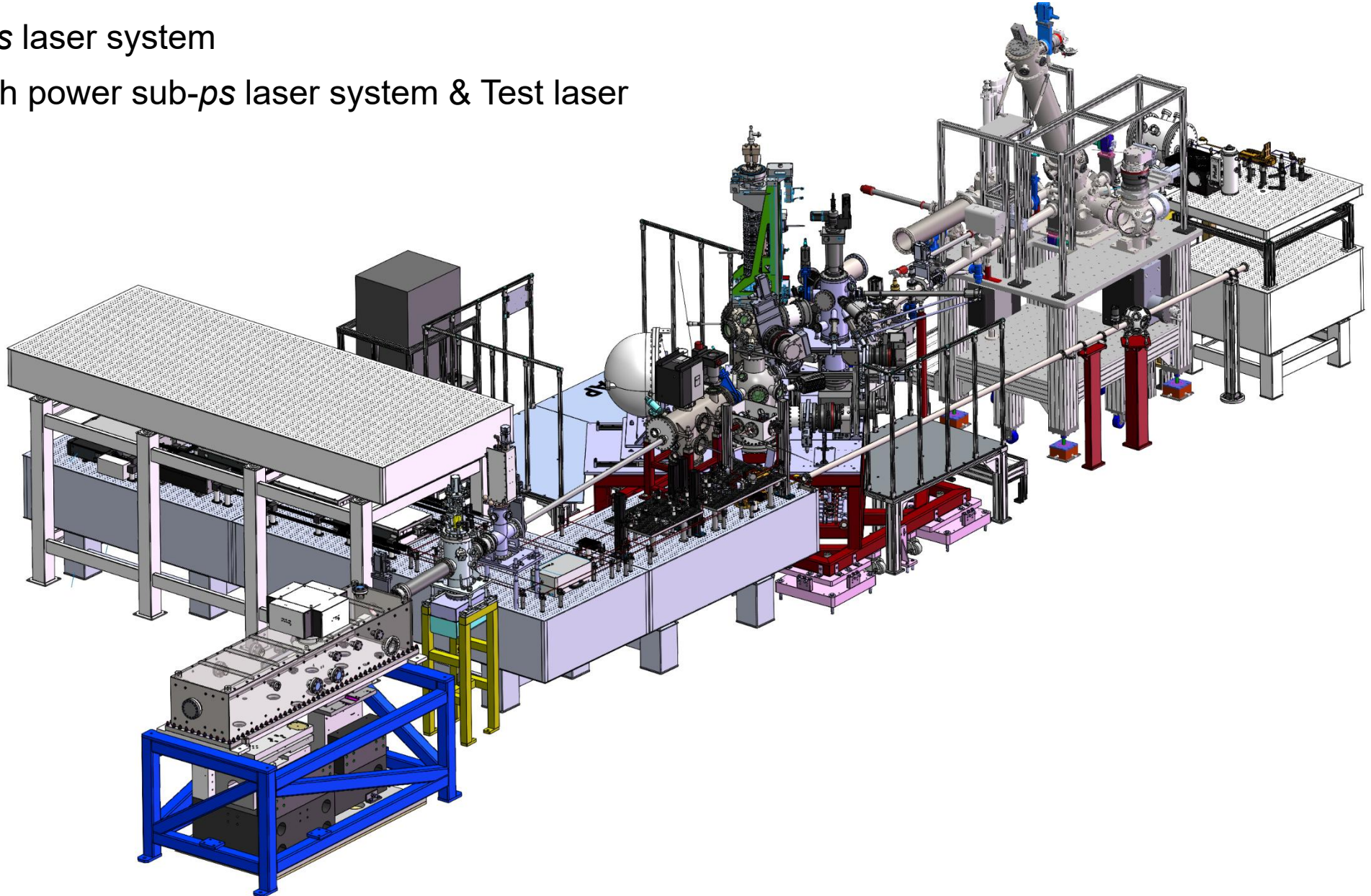


- **SES**
- **AMO**
- **SSS**

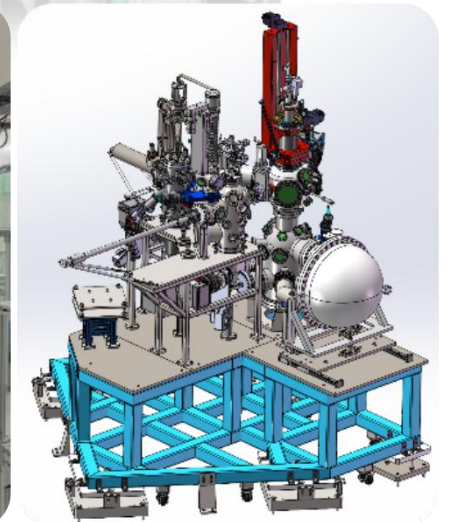
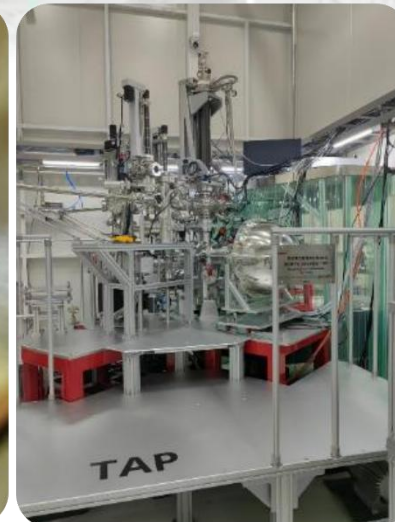
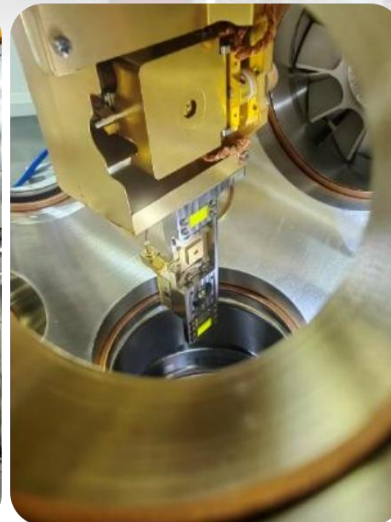
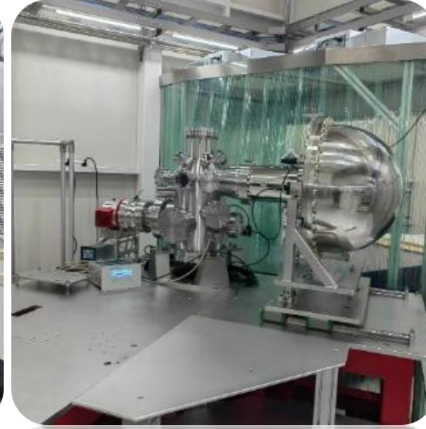
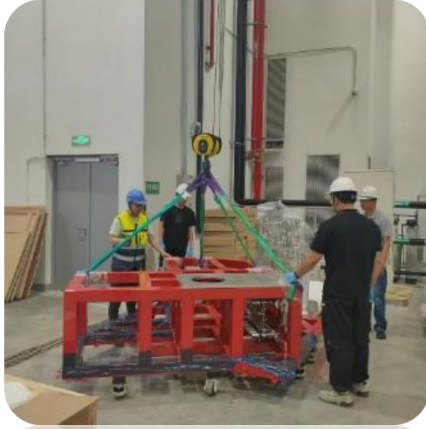
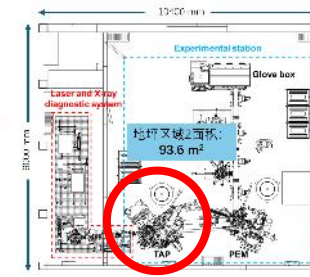




- Lower table: *fs* laser system
- Top table: High power sub-*ps* laser system & Test laser



SES TAP Progress (April)

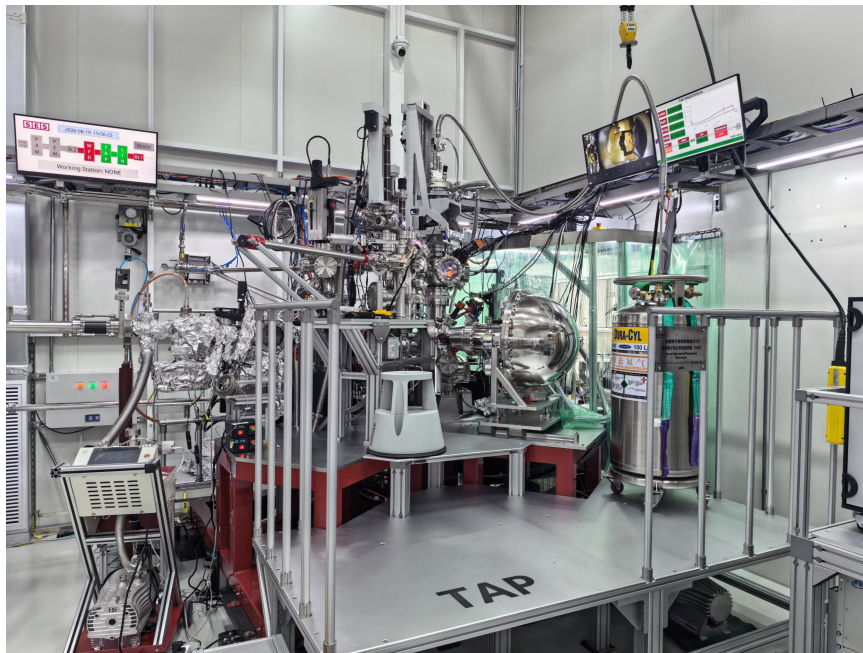


SHINE

SES has moved from installation into integrated commissioning

June–July

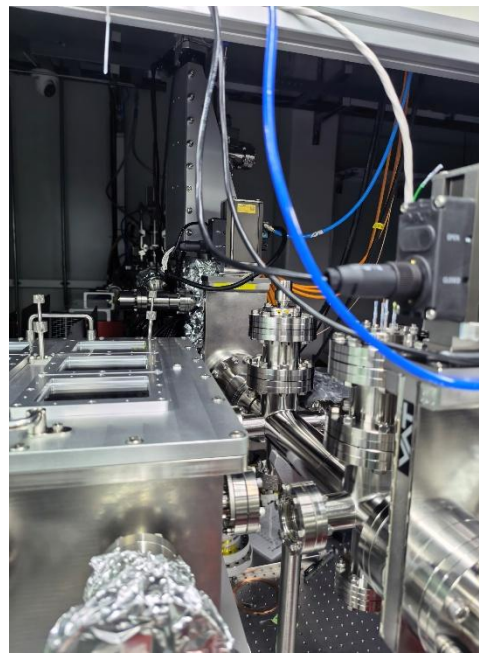
TAP bakeout completed
NEG pumps activated
main-chamber bakeout
reached 2×10^{-10} mbar



TAP commissioning

August

First ARPES band structure
from low-temperature tests



Beamline connection
between SES-KB and TAP

Early September

SES experimental section
fully connected under
vacuum

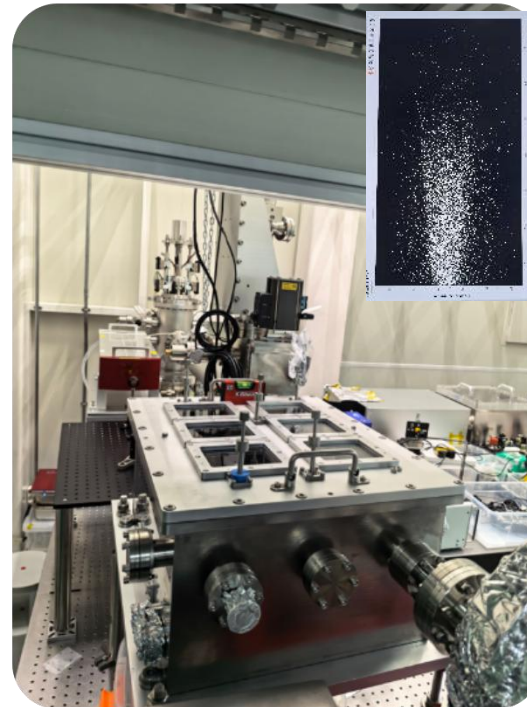


PEM integration

End-September

PEM vacuum chambers have
been installed.
main-chamber bakeout
reached 3×10^{-9} mbar

SES TAP Progress (April)



2026.Q1

- ✓ TAP motion control
- ✓ Interlock system

2026.Q2

- ✓ System bakeout
- ✓ ARPES test with lasers

2026.Q3

2026.Q4

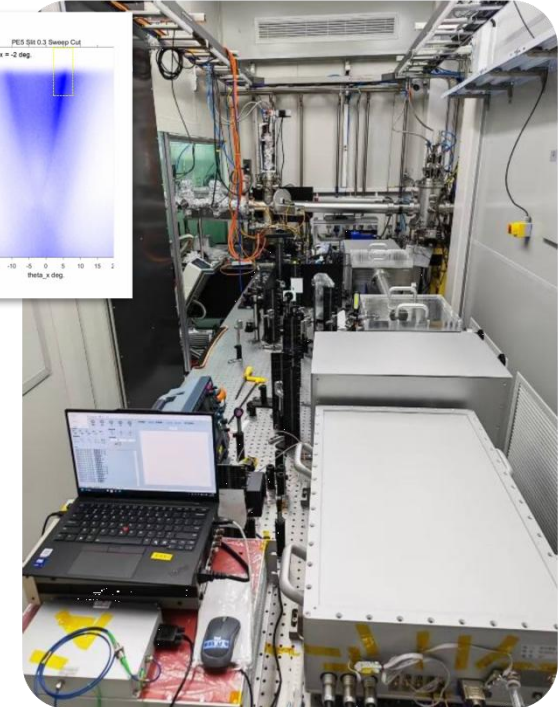
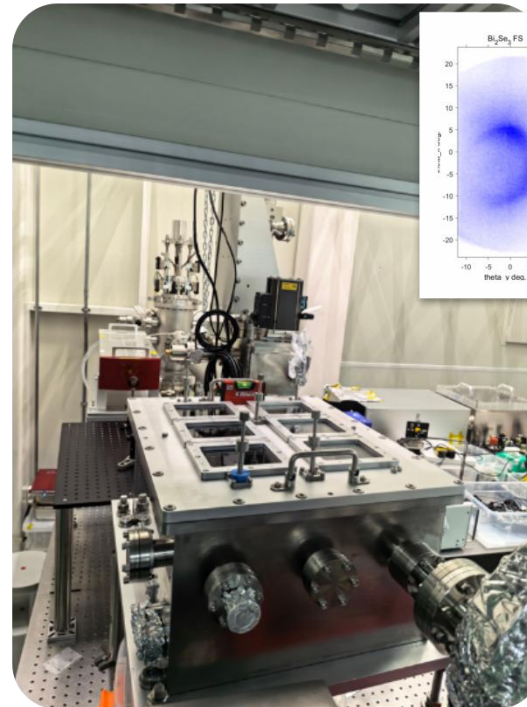


2026.10
ETA of XFEL beam

- Set up pump-probe lasers

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SES TAP Progress (October)



2026.Q1

- ✓ TAP motion control
- ✓ Interlock system

2026.Q2

- ✓ System bakeout
- ✓ ARPES test with lasers

2026.Q3

2026.Q4

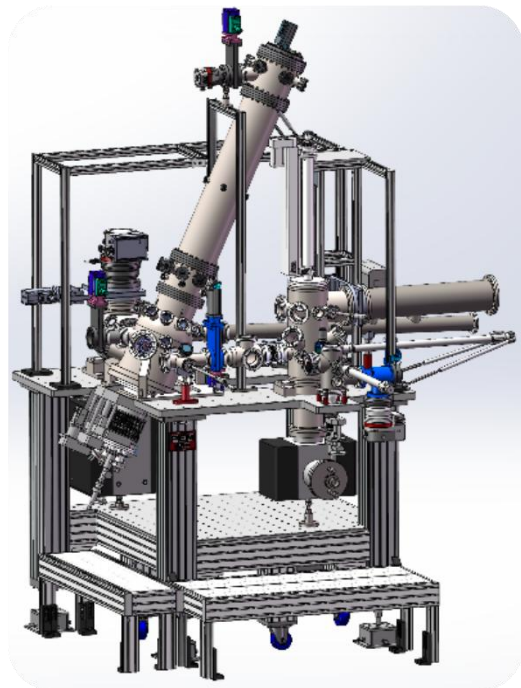
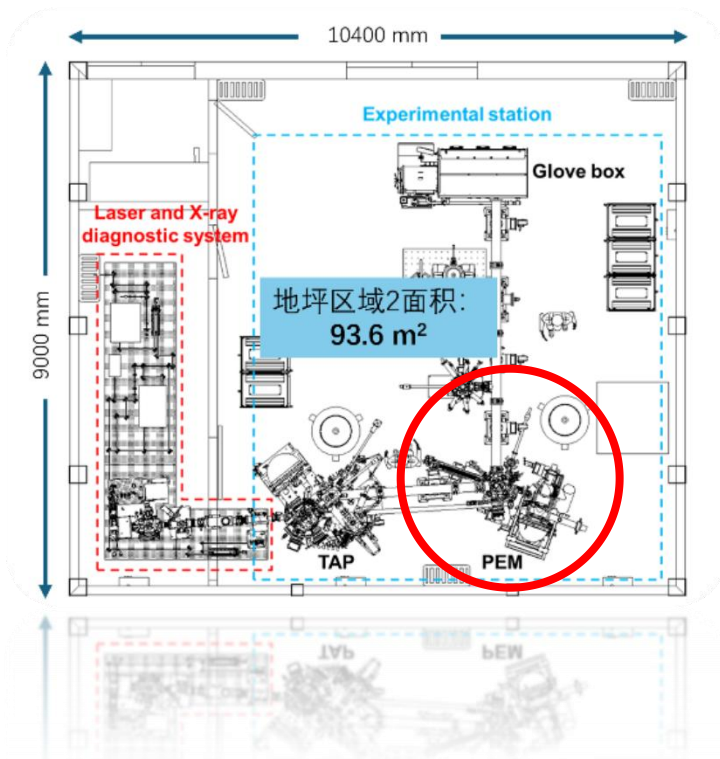


2026.10
ETA of XFEL beam

- Set up pump-probe lasers

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SES PEM Progress (April)



2026.Q1

✓ POs for components out

2026.Q2

✓ Components arrive

2026.Q3

✓ System installation

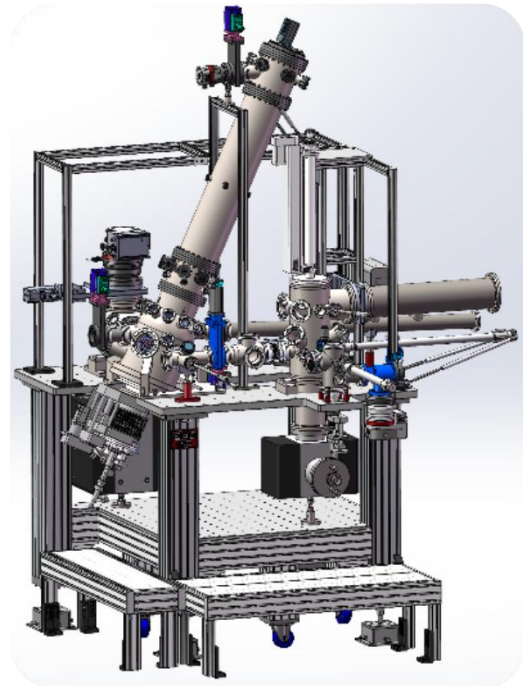
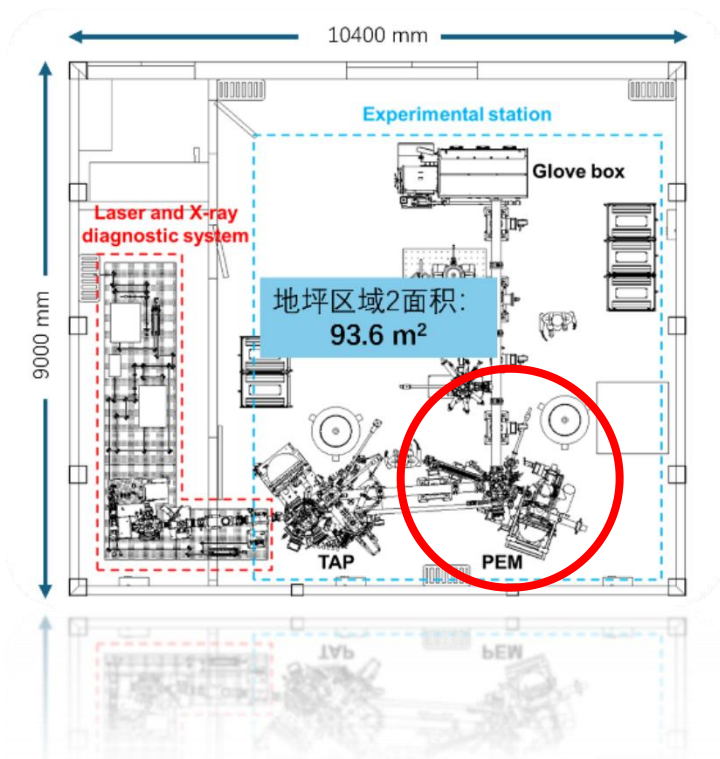
2026.Q4



2026.10
ETA of XFEL beam

▪ System test

SES PEM Progress (October)



2026.Q1

✓ POs for components out

2026.Q2

✓ Components arrive

2026.Q3

✓ System installation

2026.Q4



2026.10
ETA of XFEL beam

▪ System test



Day 1:

- **Spot size and focal position** at the sample.
- **Photon-energy calibration** across 0.2–3 keV.
- **Photon resolution / bandwidth test.**

Day 2:

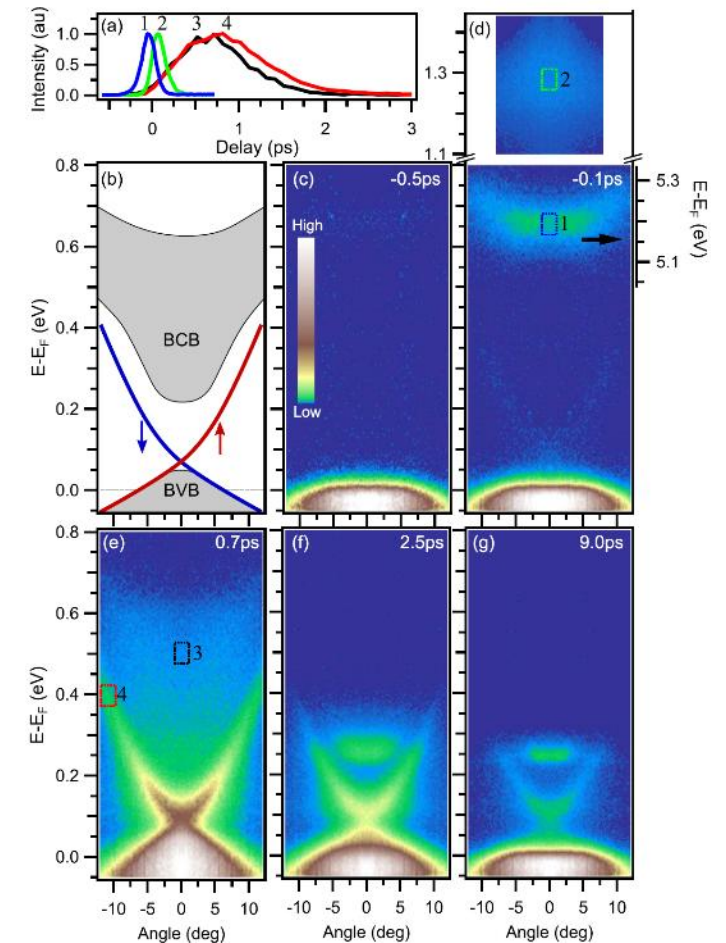
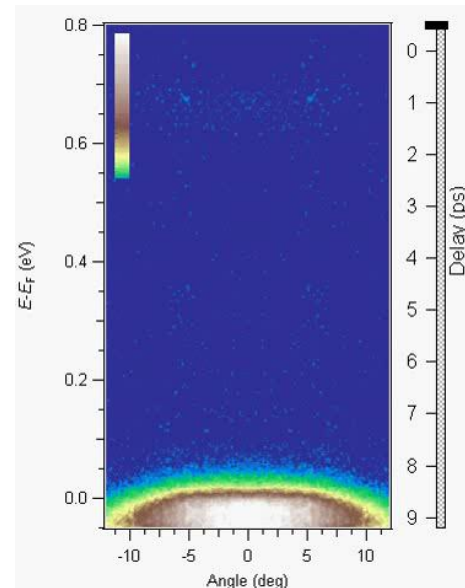
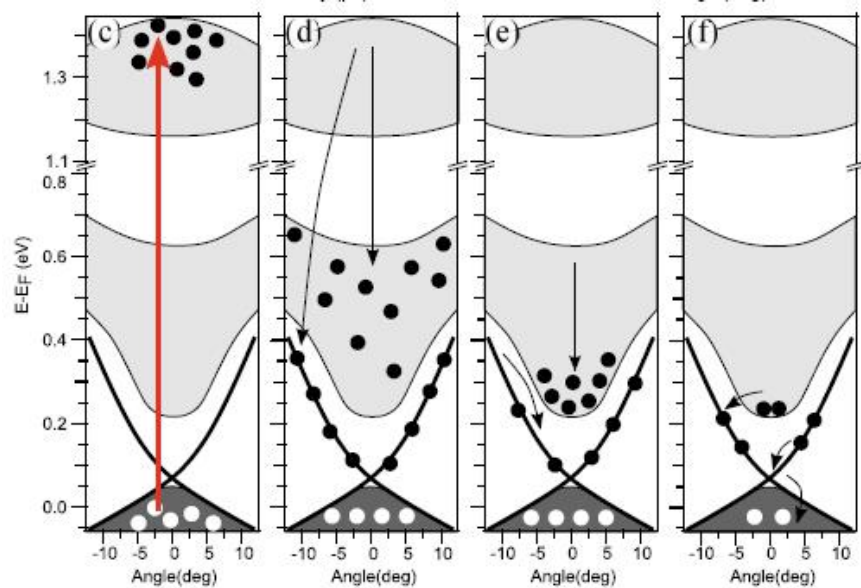
- **Flux and transmission measurement** vs energy.
- **Detector linearity / MCP-analyzer response / dead-time checks.**
- **Damage threshold / charging threshold / drift tests.**
- **Pulse-to-pulse normalization workflow** using gas monitor / intensity monitor signals.

Day 3:

- **Space-charge test:** linewidth and Fermi-edge broadening vs pulse energy.
- **Timing-jitter characterization** between pump laser and XFEL.
- **Pump–probe timing scan** on a benchmark sample with a large response.

Test on benchmark sample to Determination of temporal, momentum and energy resolution

Usual and Topological bands' dynamics



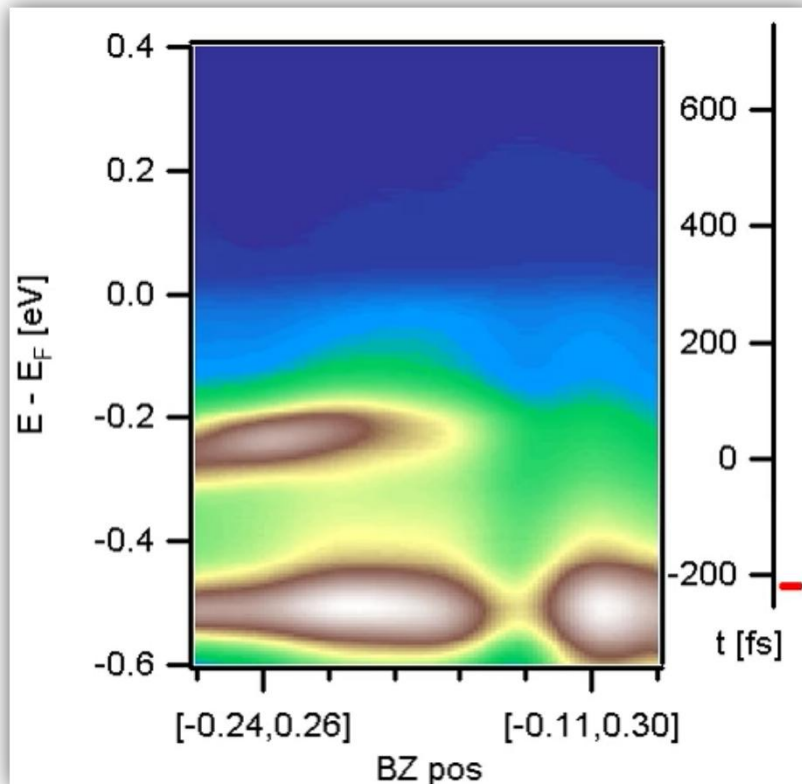
J. Sobota, et al. Phys. Rev. Lett. **108**, 117403 (2012)

SES Commissioning: Rep-rate $\geq 100\text{KHz}$ (Laser or Seeding mode)

Test on benchmark sample to
Determination of temporal, momentum and energy resolution

Ultrafast Charge Ordering Dynamics

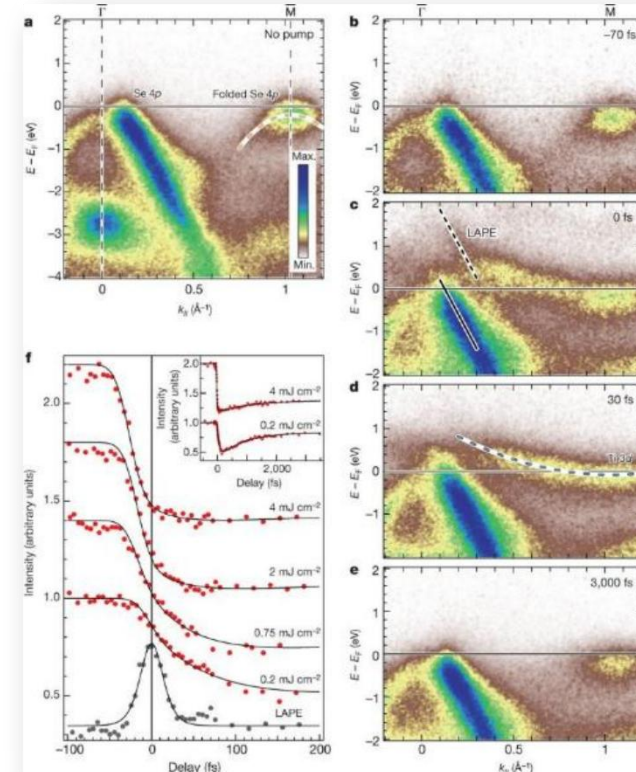
Charge ordering dynamics TbTe_3



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F. Schmitt, et. al., Science, 321, 1649 (2008)

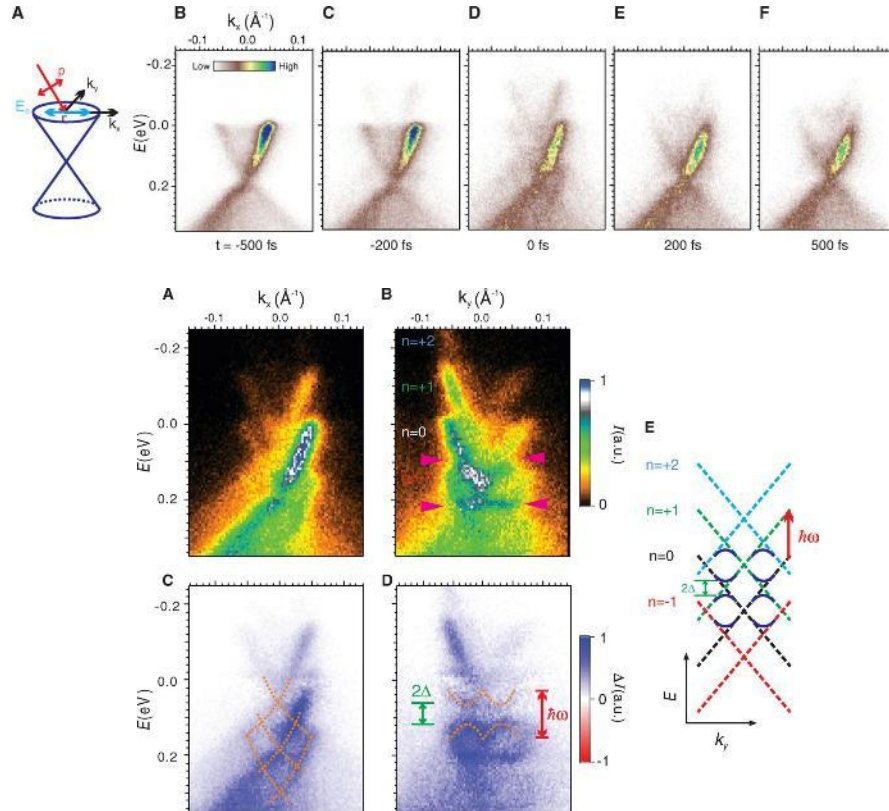
Charge ordering dynamics 1T-TiSe_2



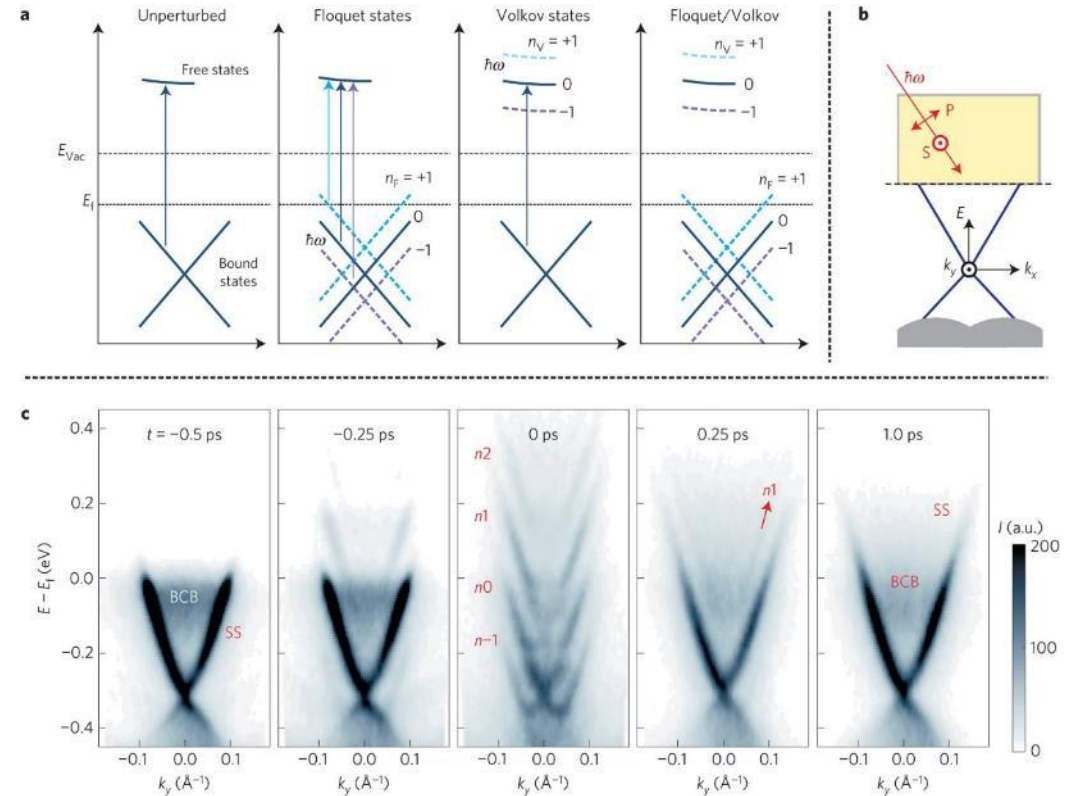
T. Rohwer, et.al., Nature, 471, 490 (2011)

SES Commissioning: Rep-rate $\geq 100\text{KHz}$ (Laser or Seeding mode)

Floquet Physics



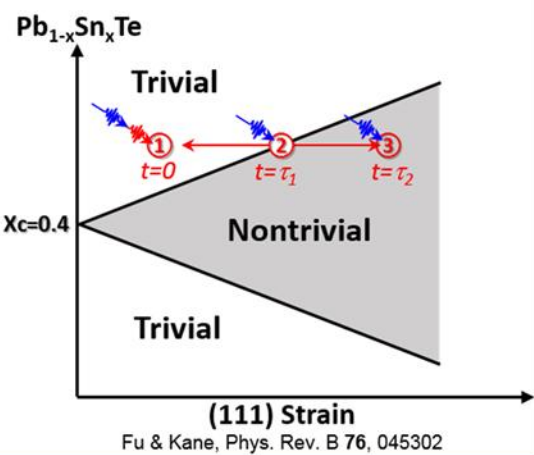
Y. Wang, et. al., *Science*, 342, 453 (2013)



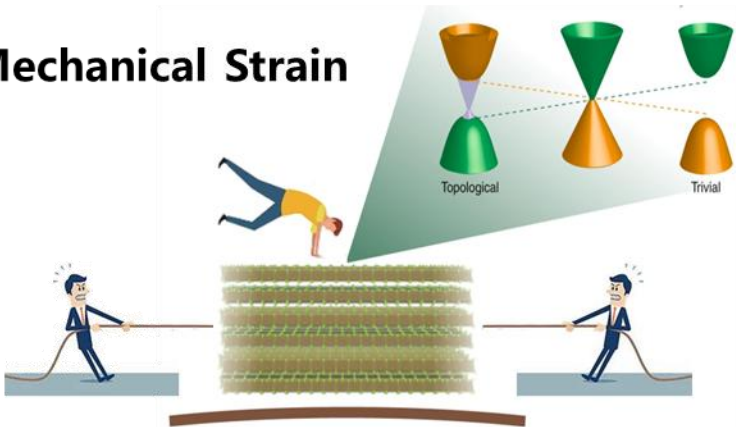
F. Mahmood, et. al., *Nature Physics*, 12, 306 (2016)

Ultra-fast Topological Phase Transition (TPT)

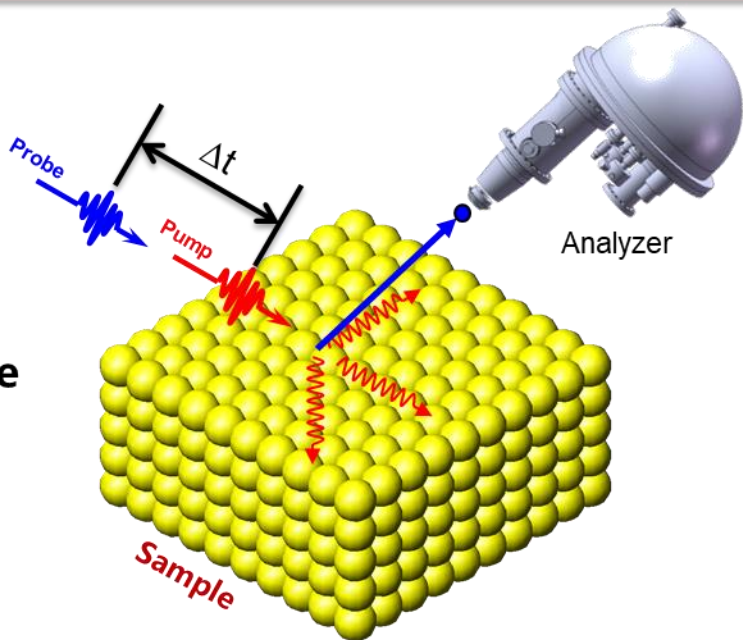
Strain induced
TPT



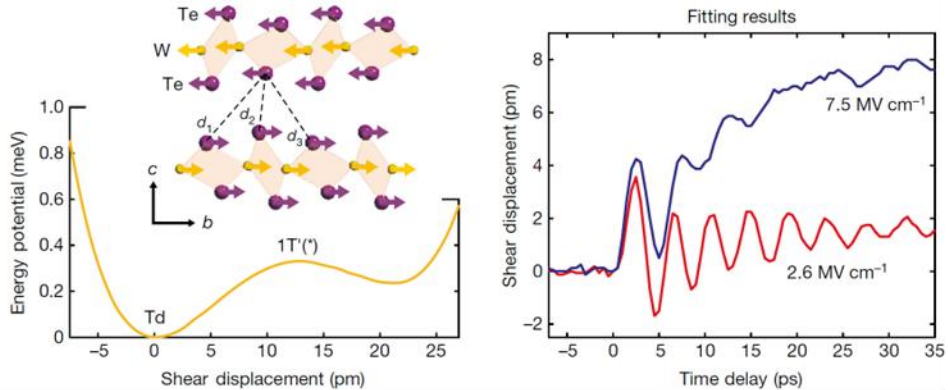
Mechanical Strain



THz Pump-
ARPES Probe

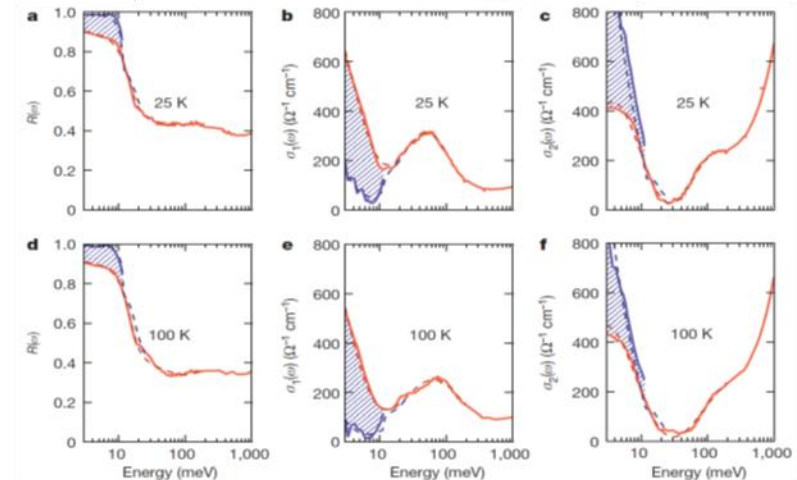
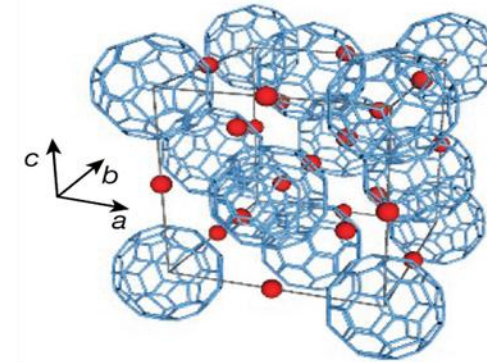
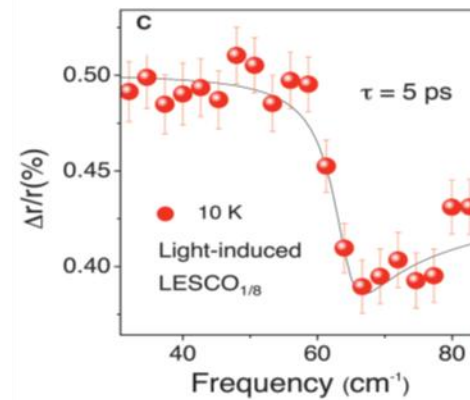
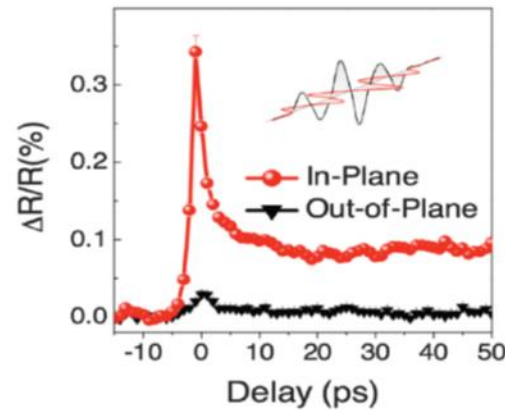
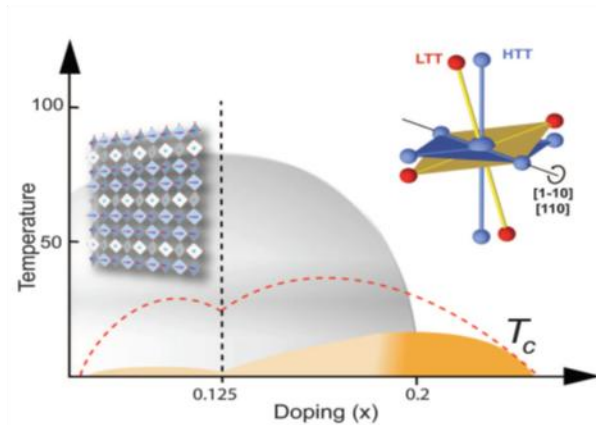
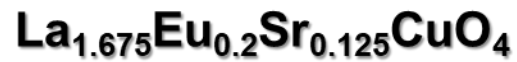


WTe₂ 1% Lattice
constant engineer



Nature 565, 61 (2019)

Transient superconductivity





- **SES**
- **AMO**
- **SSS**

Momentum imaging of ions and electrons

Super sonic gas jet

COLTRIMS

Super sonic gas jet

XFEL

Laser

MBS: magnetic bottle spectrometer

Experimental parameters:

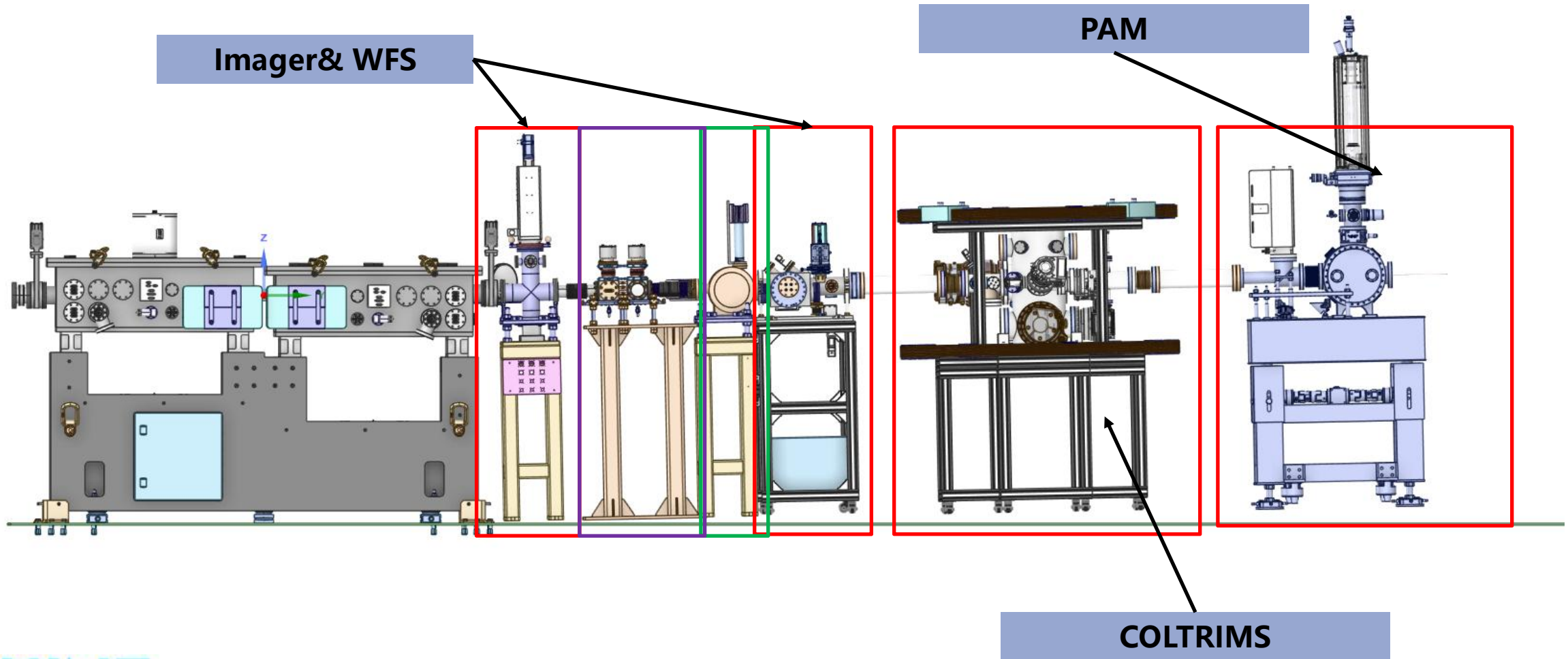
- Energy range: 0.2~3 keV
- Beam spot size: < 10 μm
- Pulse duration: 10 ~ 150 fs
- Repetition rate: 100 kHz
- Pulse energy: 10-300 μJ

- Wavelength: 266-3000 nm
- Repetition rate: 100 kHz
- Spot size: <100 μm
- Pulse energy: >100 μJ
@fundamental
- Pulse duration: 30 ~ 150 fs
- Jitter: < 40 fs

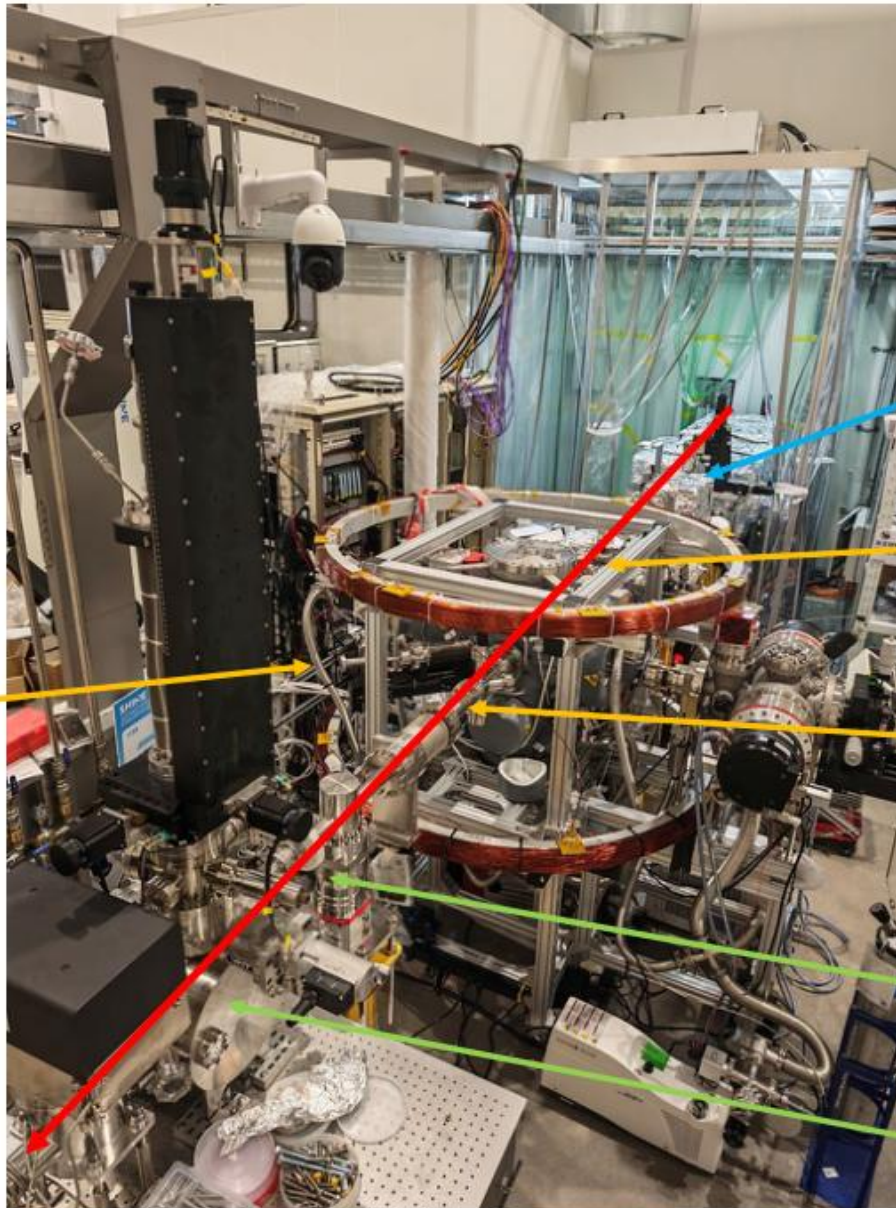
diagnostic tools:

- Beam position monitor: Imager
- Foci : imager & WFS
- Pulse flux: GMD/Hamps
- Photon energy: PES
- Pump-probe jitter: PAM

AMO Layout for the 1st beam



AMO Current status (COLTRIMS)



Gas needle

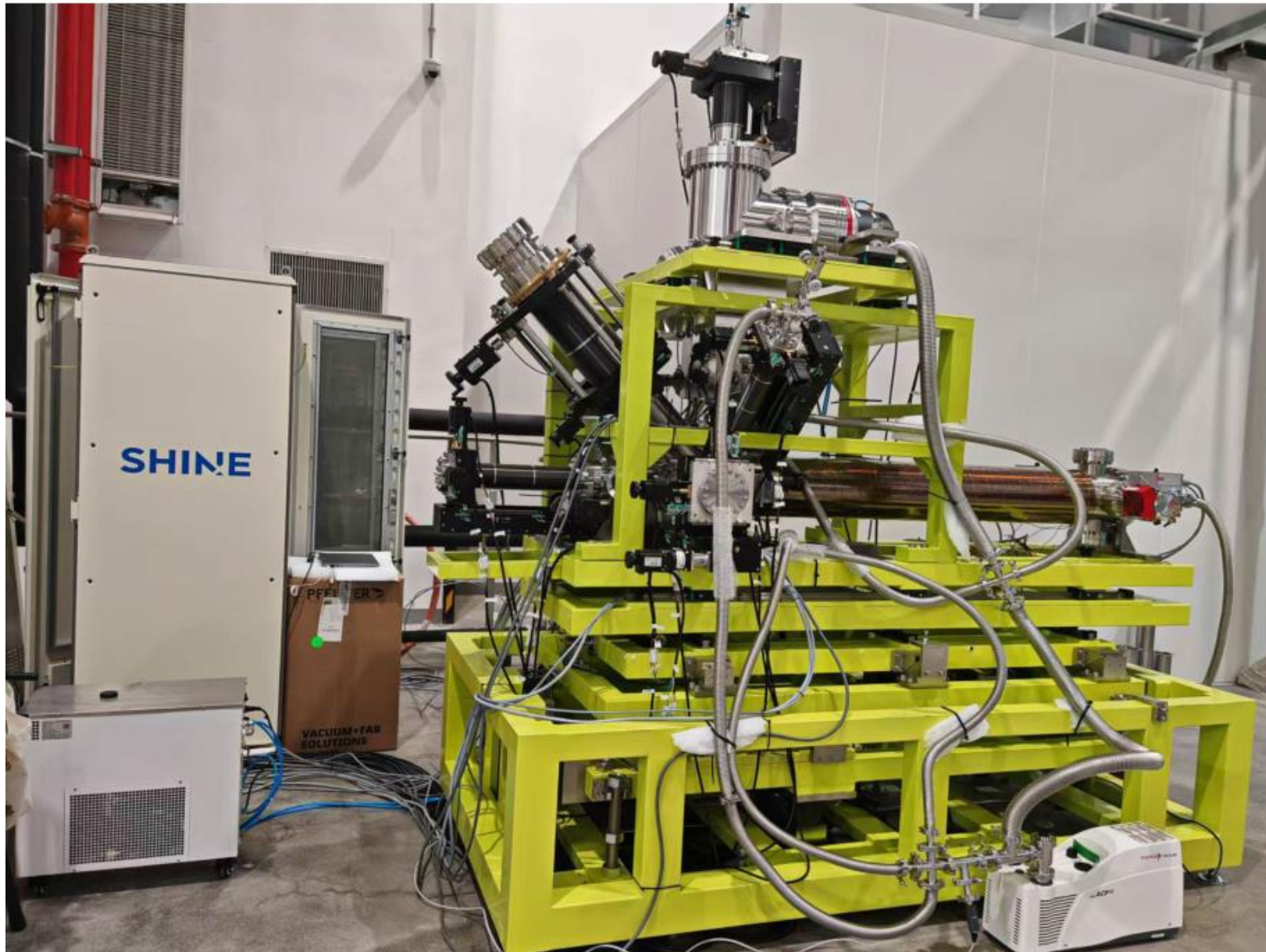
Wavefront Sensor & imager @1st focus

Ion-TOF spectrometer installed @COLTRIMS chamber

Imager after 2nd focus

Differential stage

PAM

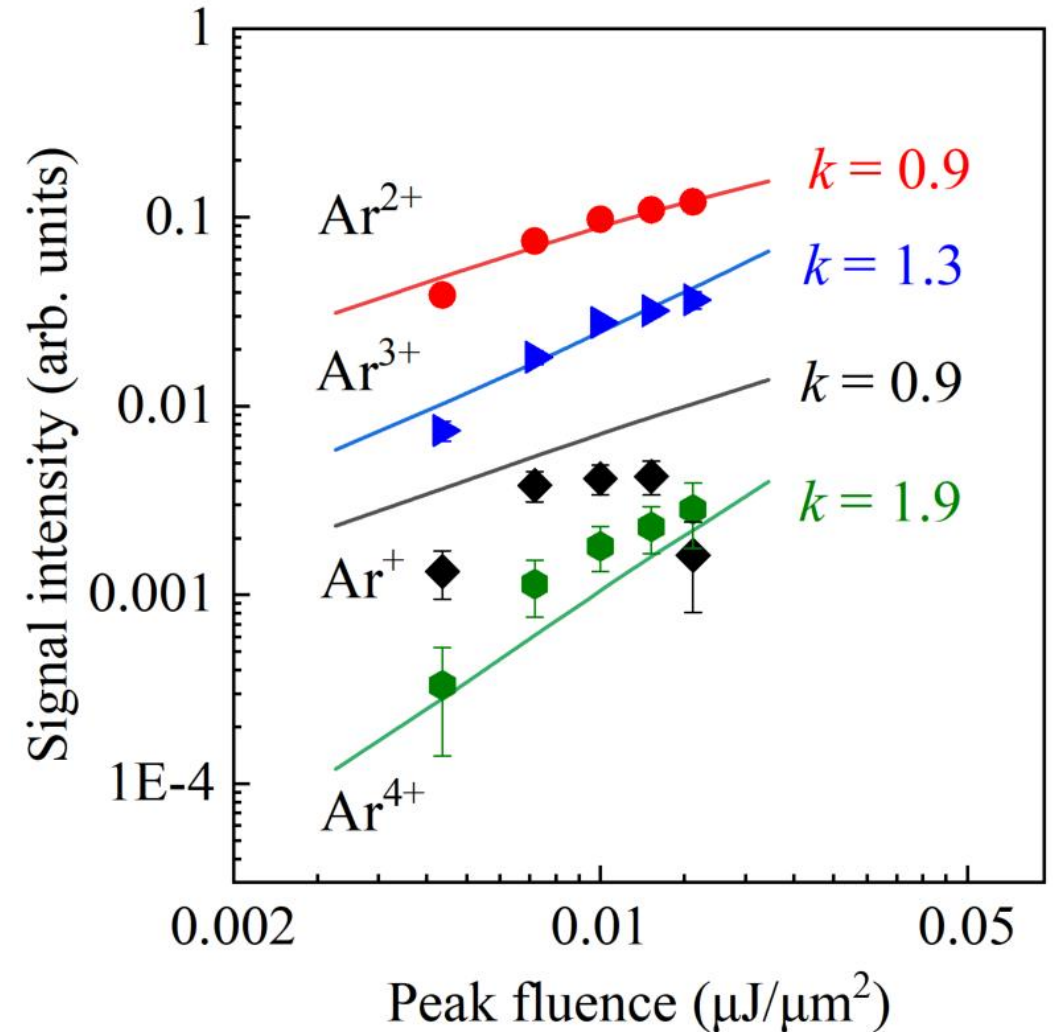
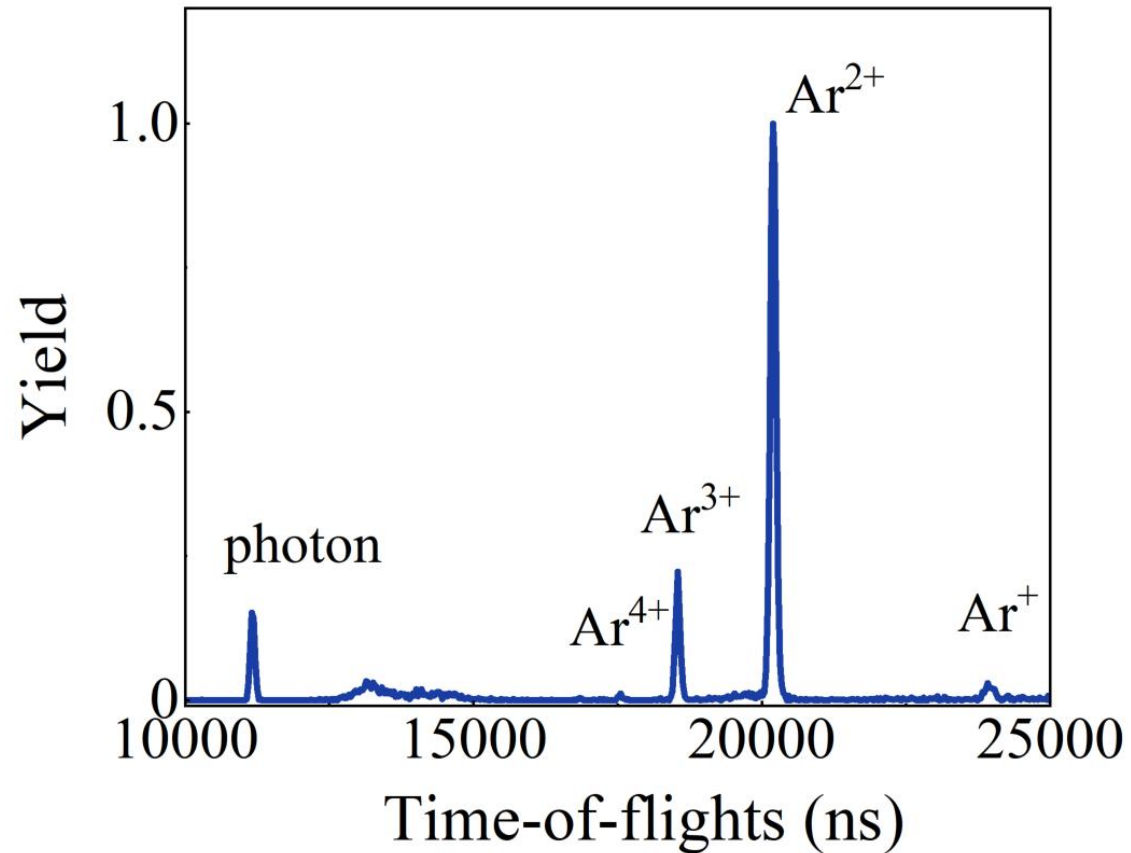


SHINE

FEL Parameters	T0	T0 +5 months	T0 +10 months
FEL MODE	SASE	SASE	SASE
Photon energy (eV)	240	100~1000	100~1000
wavelength (nm)	6.2	6.2,3.1	6.2~3.1
pulse width (fs)	~100	≤100	≤100
Repetition rate (Hz)	10	10k	100k
Pulse energy (μJ)	≥10	≥10	≥30
Pump-probe jitter	/	≤50	≤30
Trigger	Yes	Yes	Yes
Bunch ID	Yes	Yes	Yes

Based on the photon energy, the testing will be focus on Kr TOF measurement

With 4-5 days, test the spectrometer with bunchID、Time 0 and obtain intensity dependent Ar TOF measurement



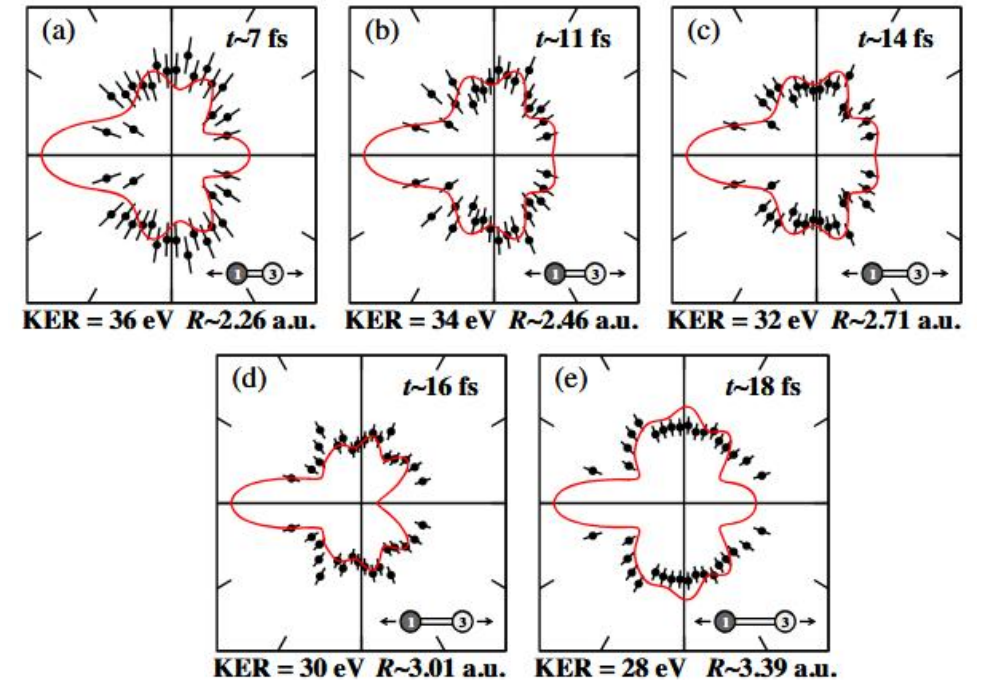
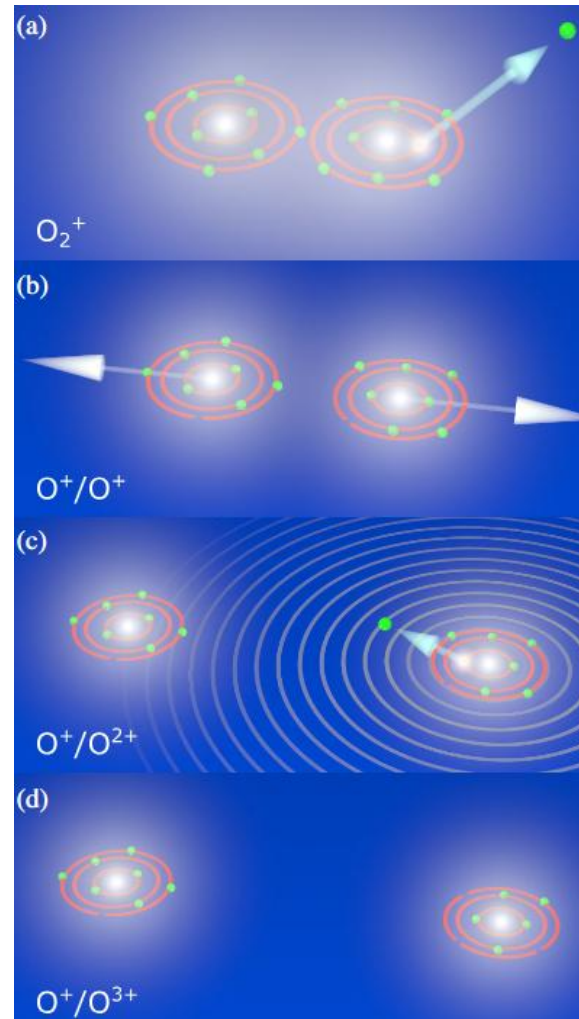


- Day 1** : Align the XFEL beam with imagers and get the timing sequence
- Day 2** : Test of the triggering time zero and get ion-TOF spectrum on-line
- Day 3** : Accumulate Data & Analyze Data along with GMD data with the same bunch ID.
- Day 4** : Accumulate Data .
- Day 5** : Accumulate Data .

FEL Parameters	T0	T0 +5 months	T0 +10 months
FEL MODE	SASE	SASE	SASE
Photon energy (eV)	200	100~1000	100~1000
wavelength (nm)	6.2	6.2,3.1	6.2~3.1
pulse width (fs)	~100	≤100	≤100
Repetition rate (Hz)	10	10k	100k
Pulse energy (μJ)	≥10	≥10	≥30
Pump-probe jitter	/	≤50	≤30
Trigger	Yes	Yes	Yes
Bunch ID	Yes	Yes	Yes

Molecular frame photoelectron angular distribution measurement

XFEL	
Photon energy	400-1000 eV
Pulse duration	~100 fs
Rep. rate	~10 kHz
Pulse energy	≥10 μJ



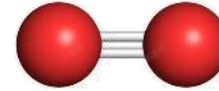
➤ quasi time-resolved imaging

Challenges from the background electrons
& multi-fold coincidence measurements

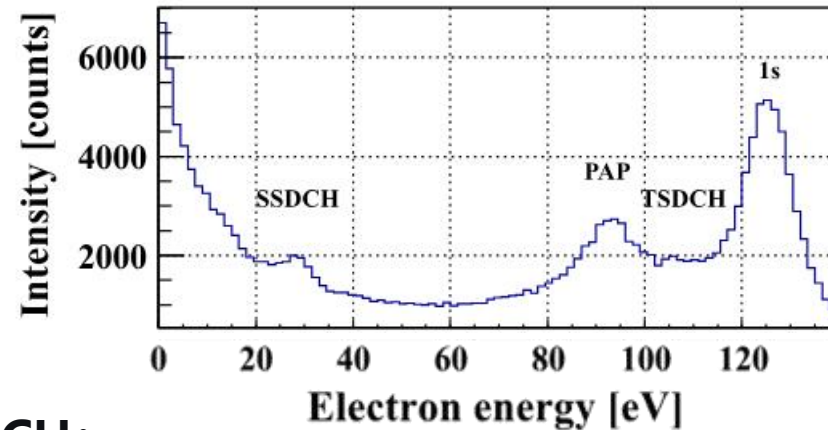
Phys. Rev. X 10, 021052 (2020)

Molecular frame photoelectron angular distribution measurement

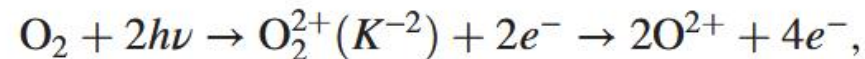
Double core-hole state related measurements



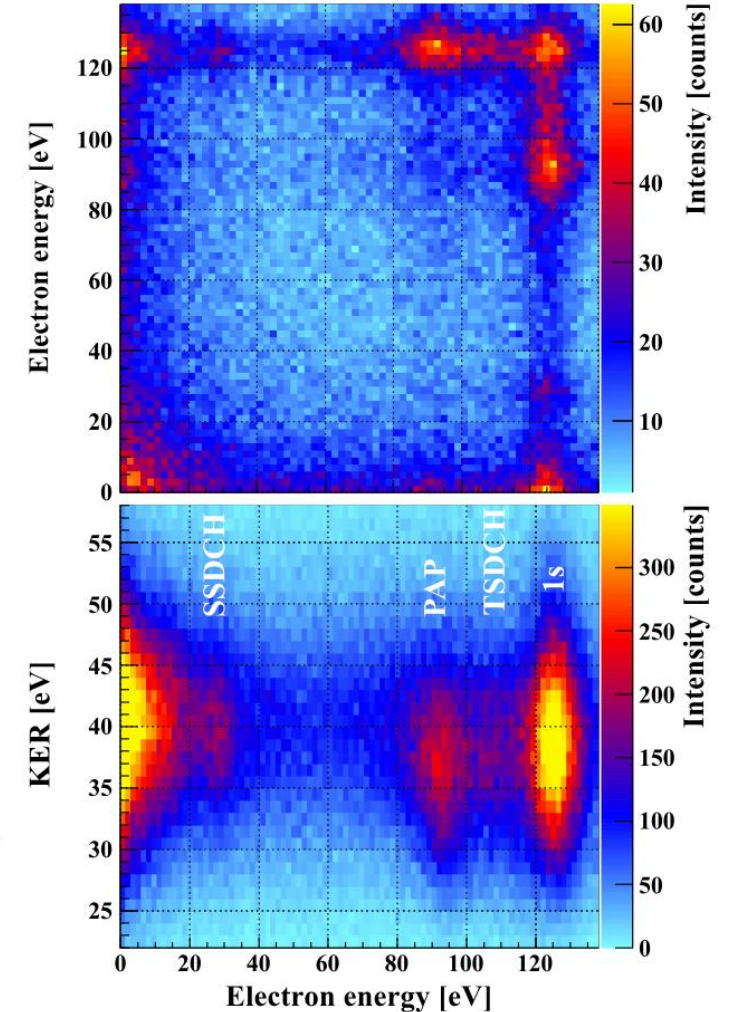
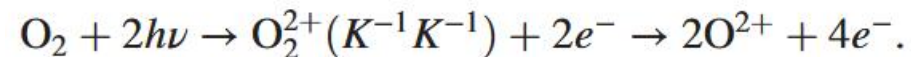
XFEL	
Photon energy	400-1000 eV
Pulse duration	<35fs
Rep. rate	~100 kHz
Pulse energy	≥30 μJ



SSDCH:



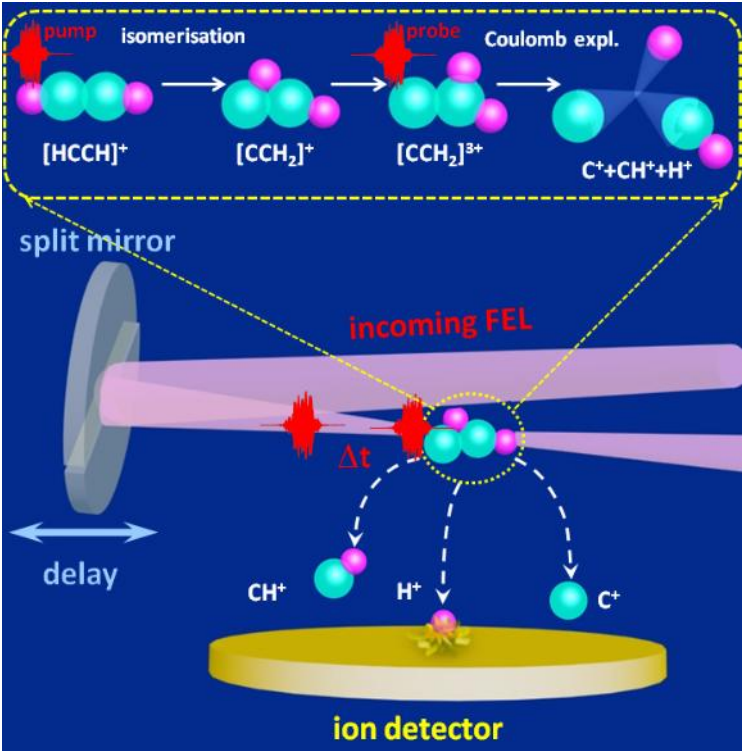
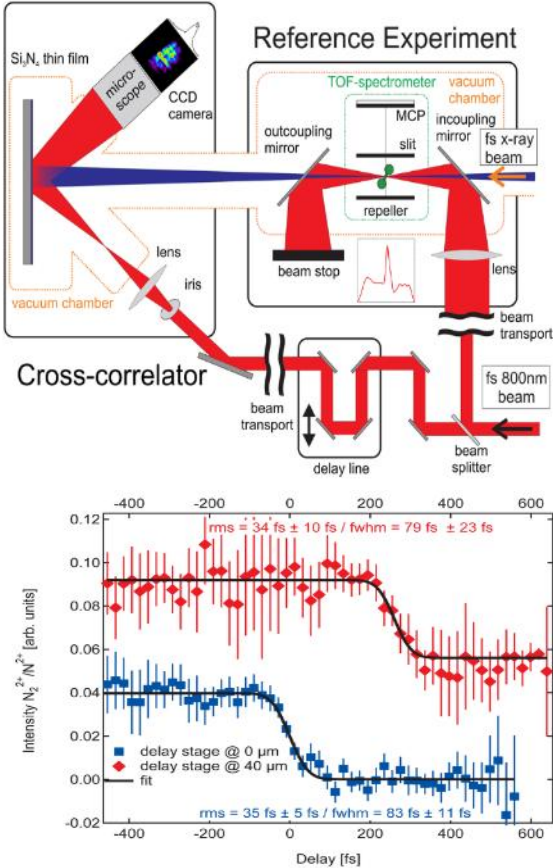
TSDCH:





Time resolve measurement of bond breaking, isomerization ...

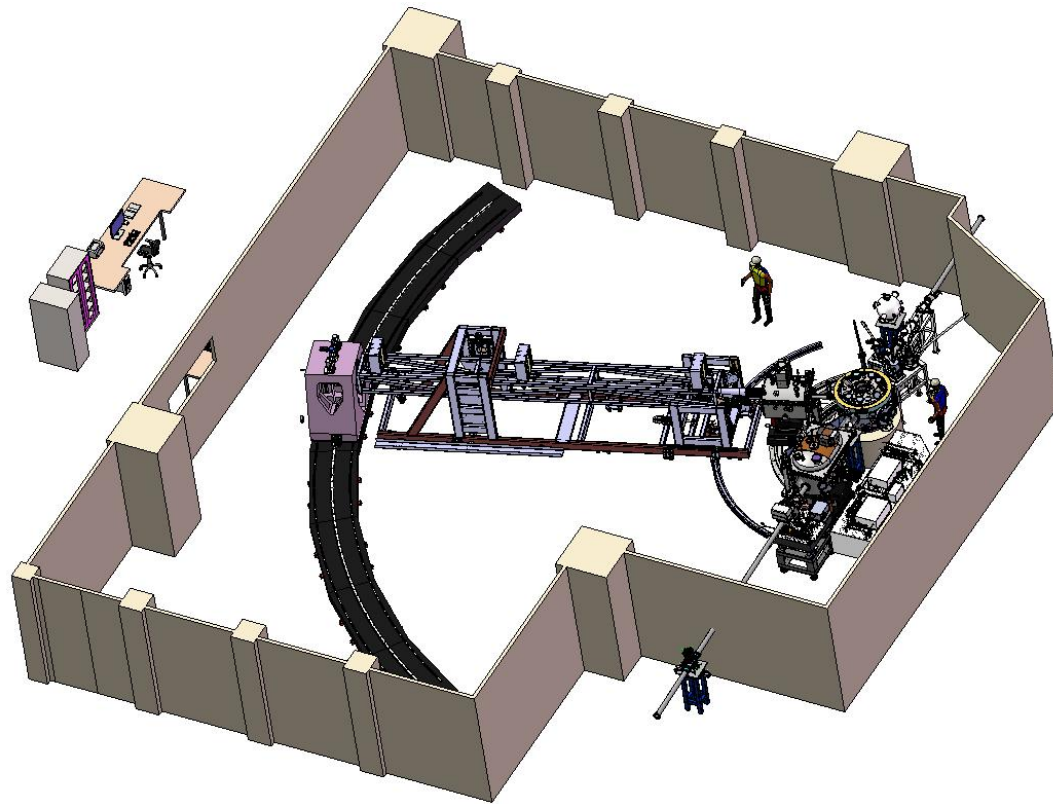
XFEL 参数	
Photon energy	200-1000 eV
Pulse duration	<35fs
Rep. rate	~100 kHz
jitter	<35fs
Pulse energy	≥30 μJ





- **SES**
- **AMO**
- **SSS**

SSS: Overview



Hatch wall

Standard
element
target

Time
diagnosis
tool

Focusing
chamber

Front
peripheral
device

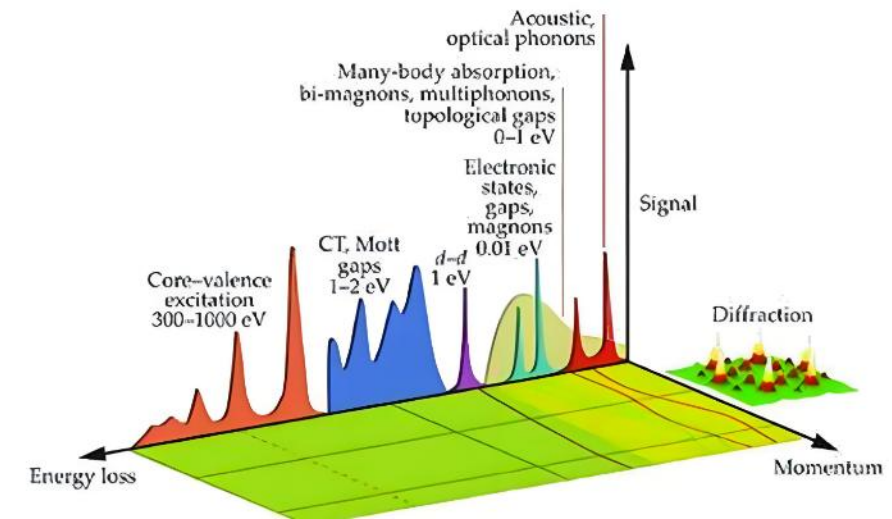
Sample
chamber

End
peripheral
device

Detector &
supporting

Signal
arm

Optics
chamber



- Time resolved (sub-ps): RIXS, RES, XAS
- Energy resolved (<50 meV): charge, spin and orbital dynamics



SSS: Overview (October)



SSS: Summary of updates



Device	Status in April	Status in Oct
Detector and supporting	Center conf.: ~40μm & ~60μm Height variation: ~ 60μm Loading deformation: ~ 15 μm	Vibration: amplification 1 + 3%; Motion accuracy tested; Project closed
Signal arm	In production	Installed; vacuum tested; Tuning rotation
Optical chamber	Mechanics was ready; optics problem	Optics problem solved; Installation in Dec
Sample chamber	Fixed ports: In production	FAT done; installation in Dec
	Sliding seal: pre-FDR	In production; delivery next year
End peripheral device	In production	Delivery in Nov.
X-ray & laser coupling chamber	N/A	Delivery in Oct.
Standard element chamber	In production	Installed; Project closed
Laser alignment chamber	N/A	Delivery in Oct.



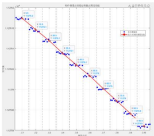
SSS: Construction progresses

Construction - Detector and supporting

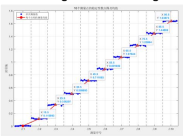


	01(极高点)	02(极高点)	放大率(极高点)		01(极低点)	02(极低点)	放大率(极低点)
D ₀ -Z	128.60	113.87	1.002	D ₀ -Z	142.62	106.20	0.999
G ₂	123.81	117.85		G ₂	137.49	110.40	
D ₀ -E	114.01	103.01	1.014	D ₀ -E	130.99	92.78	1.001
G ₁	111.53	102.33		G ₁	129.23	93.85	
D ₀ -N	103.01	107.43		D ₀ -N	105.3	92.69	1.013
G ₁	102.39	101.15	1.034	G ₁	106.77	89.16	

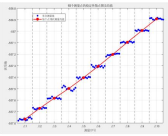
radius 0.03mm



angular 0.001degree

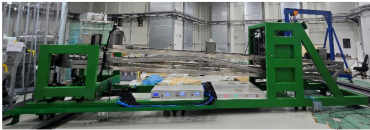


Vertical 0.1mm



Construction – signal arm

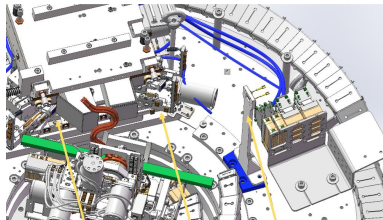
3.5 T weight v.s. floor condition



Vacuum test:



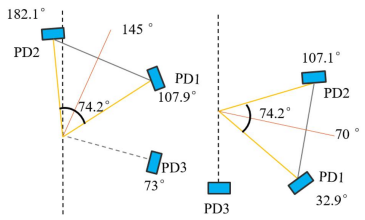
Construction – in-chamber PDs



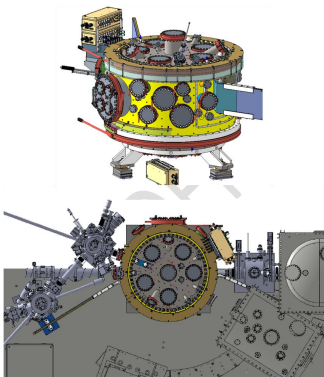
PD2

PD1

PD3

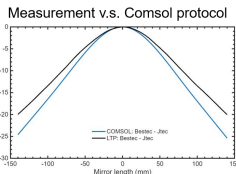


Construction – sample chamber sliding seal

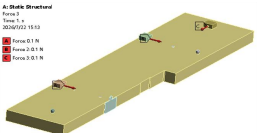


Serial	Part	Serial	Part
1	Changed angle and distance	1	Changed angle and distance
2	Changed distance from 0 to 100 from the sample position and distance	2	Changed distance from 0 to 100 from the sample position and distance
3	Changed position and distance	3	Changed position and distance
4	Changed angle, position and distance	4	Changed angle, position and distance
5	Same position	5	Same position
6	Changed position and distance	6	Changed position and distance
7	Regulated to 0.1	7	Regulated to 0.1
8	Changed distance, position and distance	8	Changed distance, position and distance
9	Same position	9	Same position
10	Changed angle and distance	10	Changed angle and distance
11	Same position	11	Same position
12	Changed angle and distance	12	Changed angle and distance
13	Regulated to 0.1	13	Regulated to 0.1
14	Changed angle and distance	14	Changed angle and distance
15	Changed distance	15	Changed distance
16	Changed distance	16	Changed distance
17	Regulated to 0.1	17	Regulated to 0.1
18	Changed distance	18	Changed distance
19	Changed distance	19	Changed distance
20	Changed distance	20	Changed distance
21	Changed distance	21	Changed distance
22	Removed	22	Removed
23	Changed angle and distance	23	Changed angle and distance
24	Changed angle and distance	24	Changed angle and distance
25	Changed angle and distance	25	Changed angle and distance
26	Changed distance	26	Changed distance
27	Changed distance	27	Changed distance
28	Changed distance	28	Changed distance
29	Changed distance	29	Changed distance
30	Changed angle and distance	30	Changed angle and distance
31	Changed angle and distance	31	Changed angle and distance
32	Changed angle, position and distance	32	Changed angle, position and distance
33	Removed	33	Removed
34	Changed distance	34	Changed distance
35	Changed distance	35	Changed distance
36	Changed distance	36	Changed distance
37	Changed angle and distance	37	Changed angle and distance
38	Same position	38	Same position
39	Changed angle and distance	39	Changed angle and distance

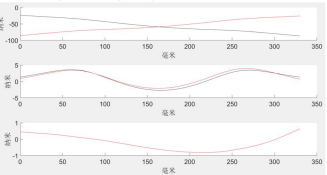
Construction – optical chamber



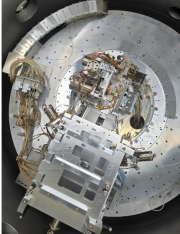
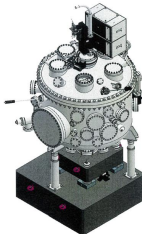
Bessel support + side security protection



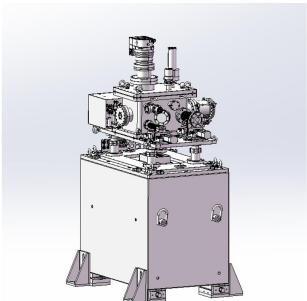
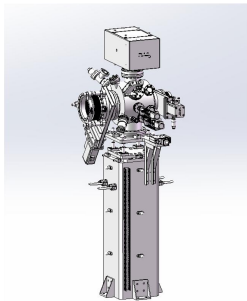
Securing force + gravity considered deformation



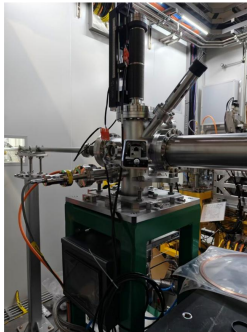
Construction – sample chamber fixed ports



Construction – coupling chamber & alignment chamber



Construction – Standard element chamber

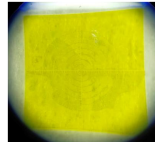


- 16 slots for different element combination.

166	G-201 (重图)
154	S-103 (重图)
148	H
172	134 W
158	124 BuT03
150	114 NiO
136	104
128	94
114	84 M-202
106	74 S-202
92	64
84	54 S-103
70	44 VO2
62	34 G-202
48	24 T-202
40	14 T-202
22	140P-2
10	140P-1
0	0

图2 标注信息、位置与电机电行程关系示意图 (左) 流样品托设计 (右)

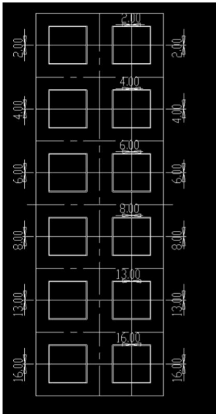
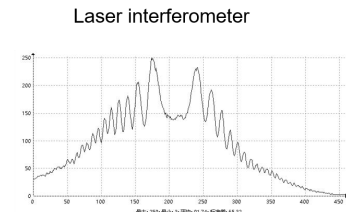
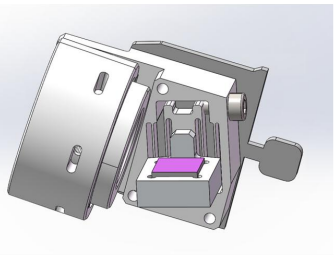
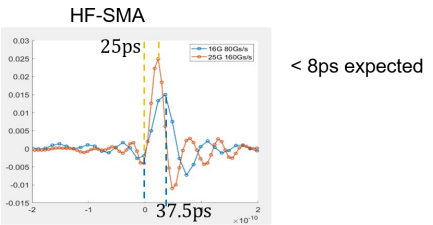
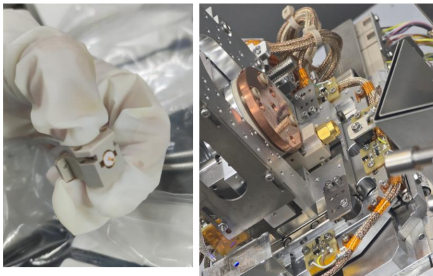
- Marked YAG for alignment



SSS: Testing progresses



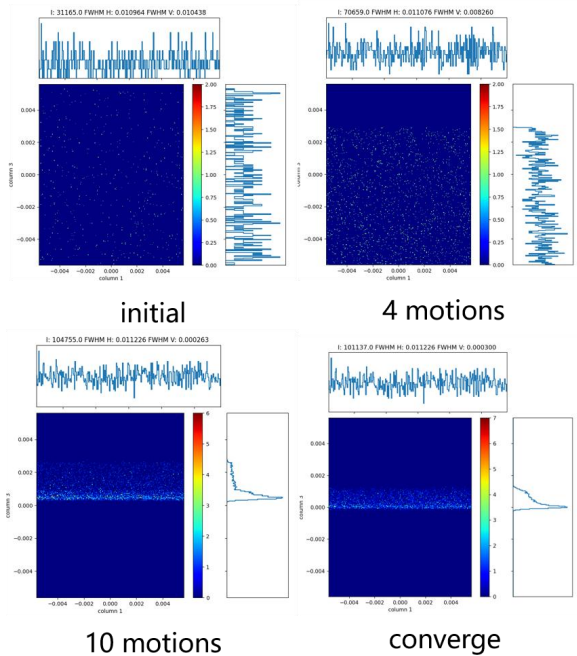
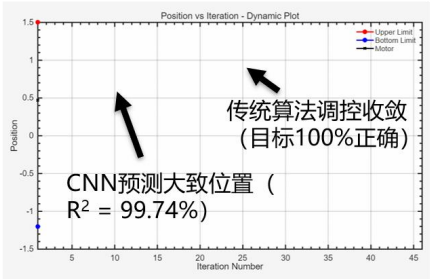
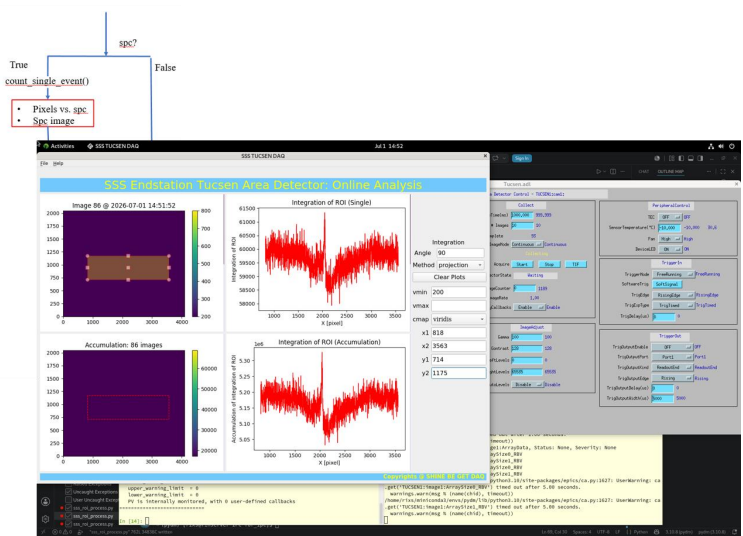
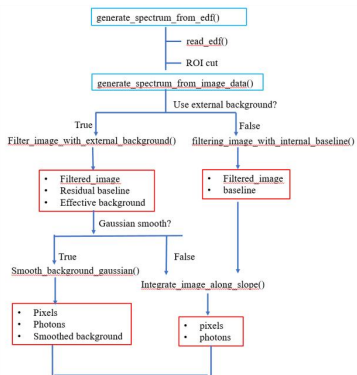
Spatial and temporal overlap



AI assisted alignment

- Convolutional Neural Network + golden-section search
- Tested with focusing mirror motion
- Will expand to full freedom after framework test

Data collection



SSS Scientific planning:

energy range: 400~1700eV

energy resolution:

On day-one	Design objective
100meV@930eV	50meV@930eV

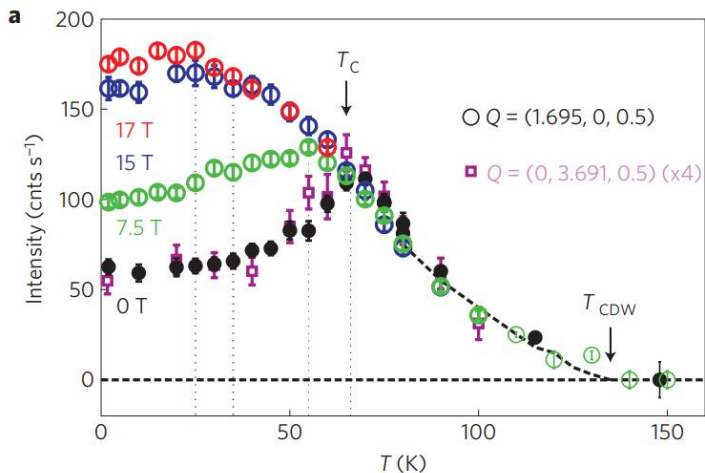
Initial measurements @ resolution ~100meV, rep-rate ~ 10K:

1. Optical triggered chemical process (photosynthesis) ;
2. Quasi-elastic response & inelastic response of the orderings in electron-correlated materials;

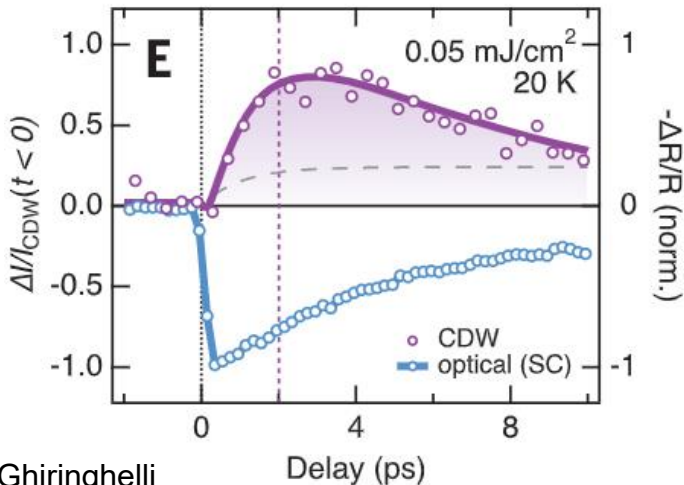
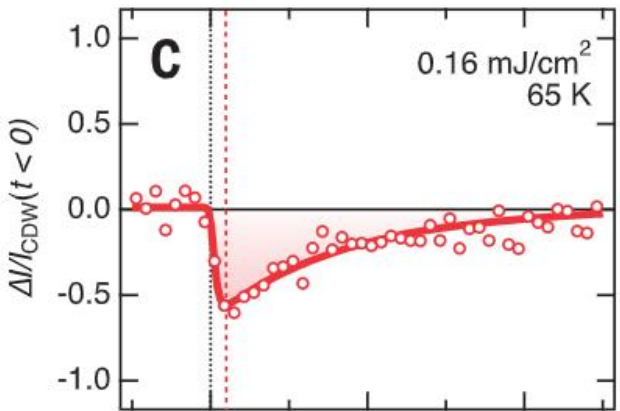
Cuprates :

CDW, SDW, phonon coupling, charge plasmon, charge continuum etc.

SSS Scientific planning: local exchange v.s. charge excitation



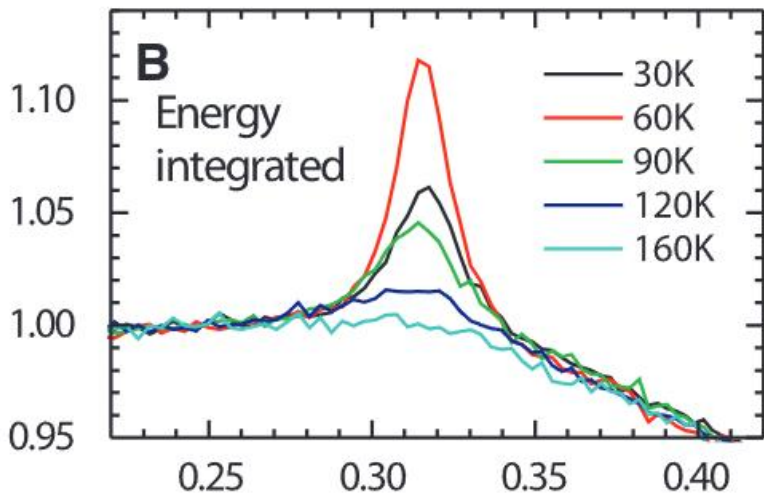
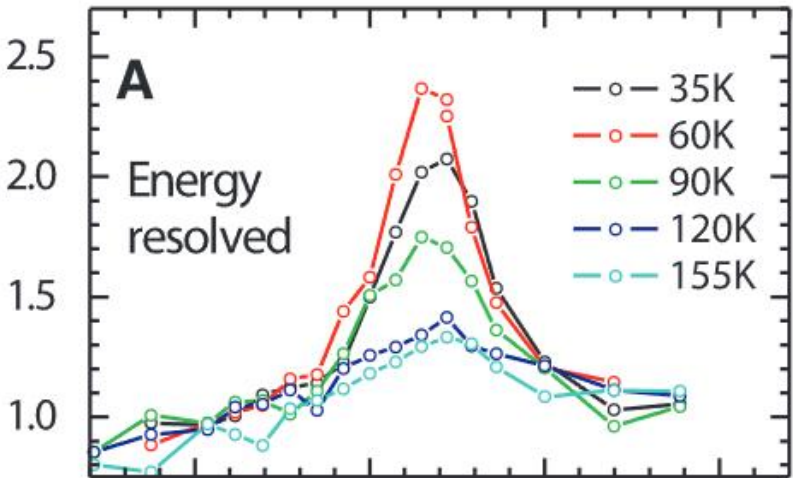
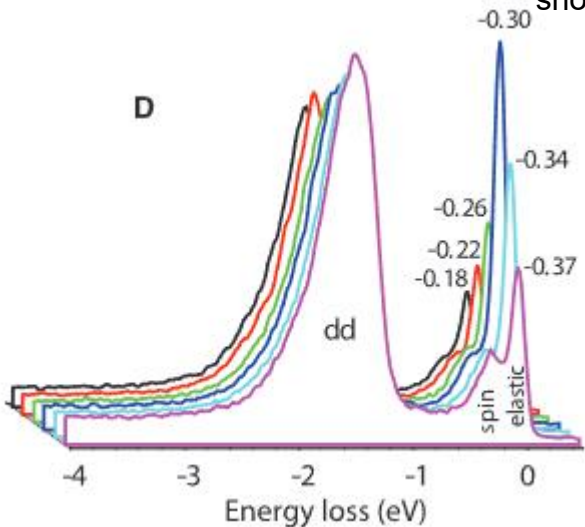
Wandel et al. Science (2022) tr-RXS



J. Chang et al. NATURE PHYSICS 2012

Conventional RXS signal – very slow response under $T_c \rightarrow ???$

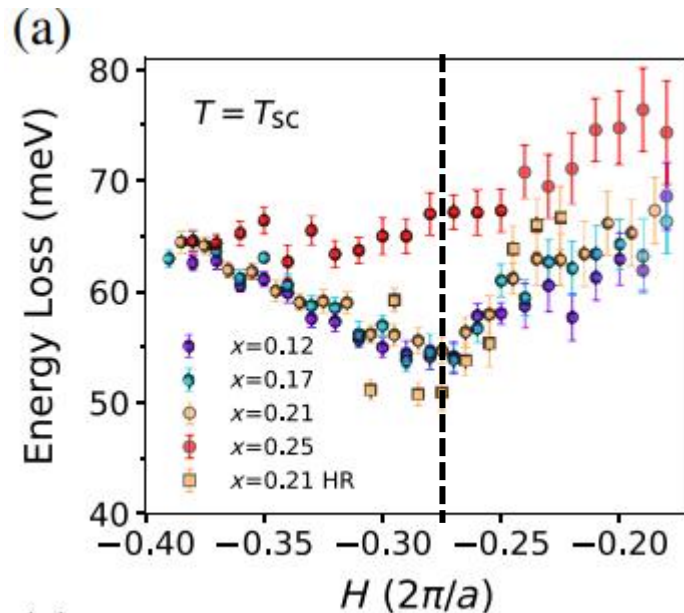
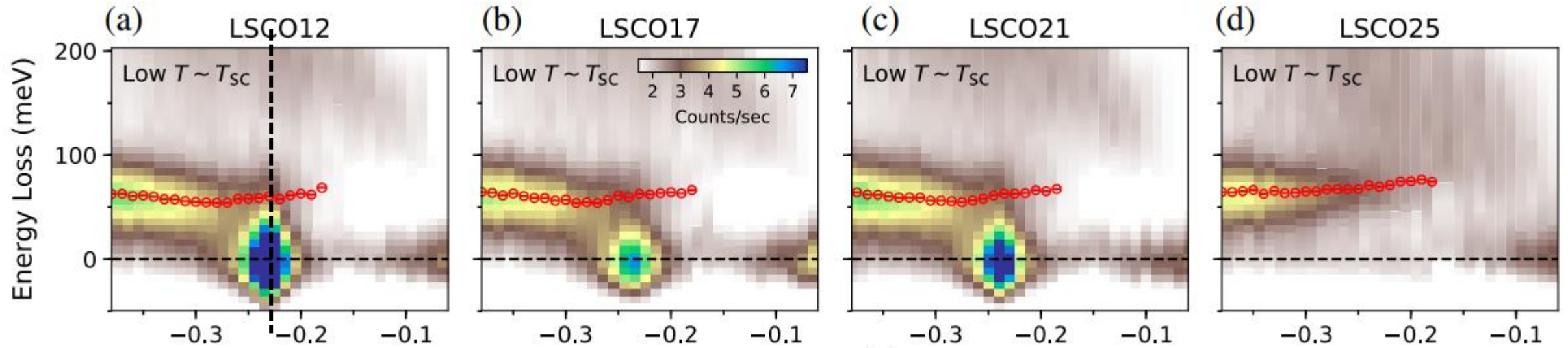
Conventional RXS signal has more contribution from other channels $\rightarrow$ Ghiringhelli showed that the varied signal is 10% of total.



G. Ghiringhelli et al. Science 2012

SSS Scientific planning: CDW vs E-ph coupling

J. Q. Lin et al. PRL 2020

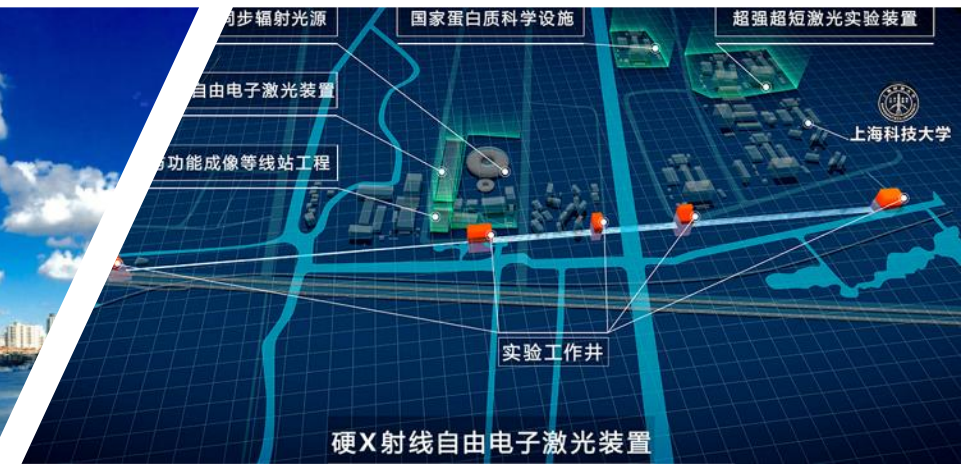


- A clear coupling of the CDW v.s. phonon softening
- A clear mismatch of the CDW ordering wavevector v.s. phonon softening center Q

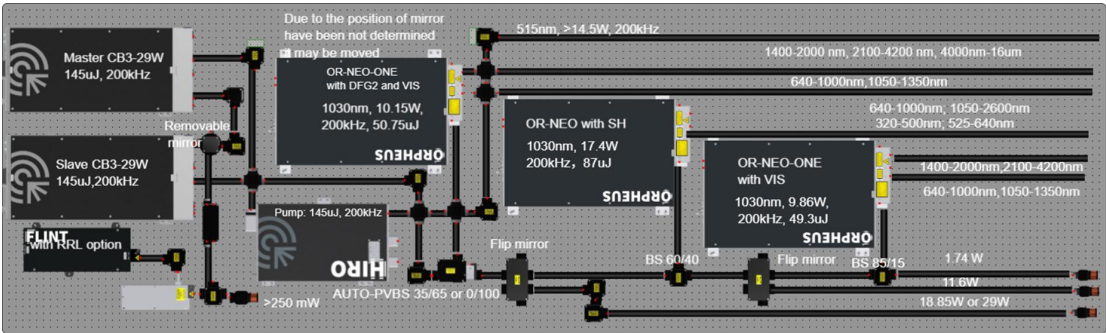
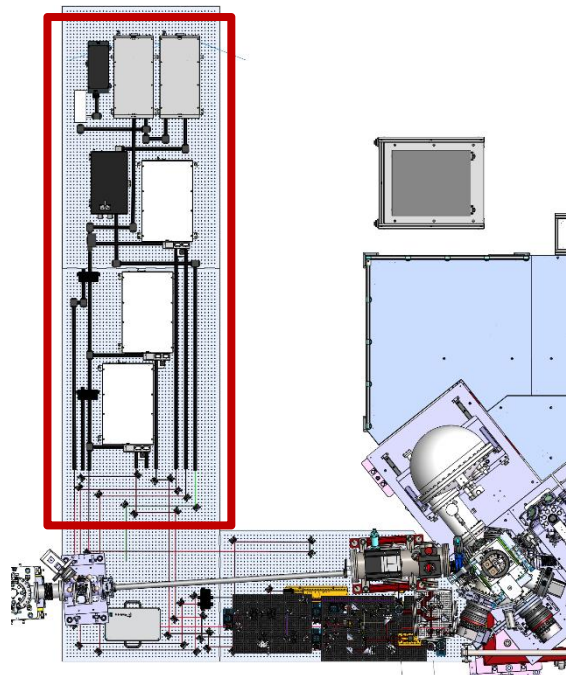
What is the role of electron-phonon coupling for SC in the cuprates?



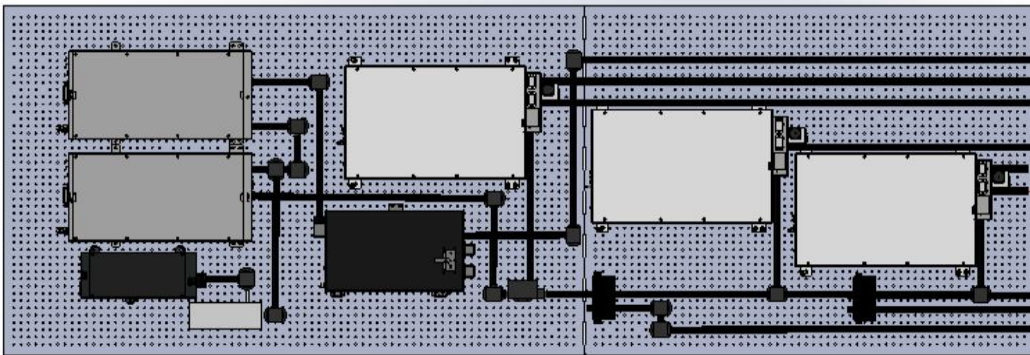
Thank you for your attention!



Lower level: Laser source (LC carbide X2 + OPA X3)



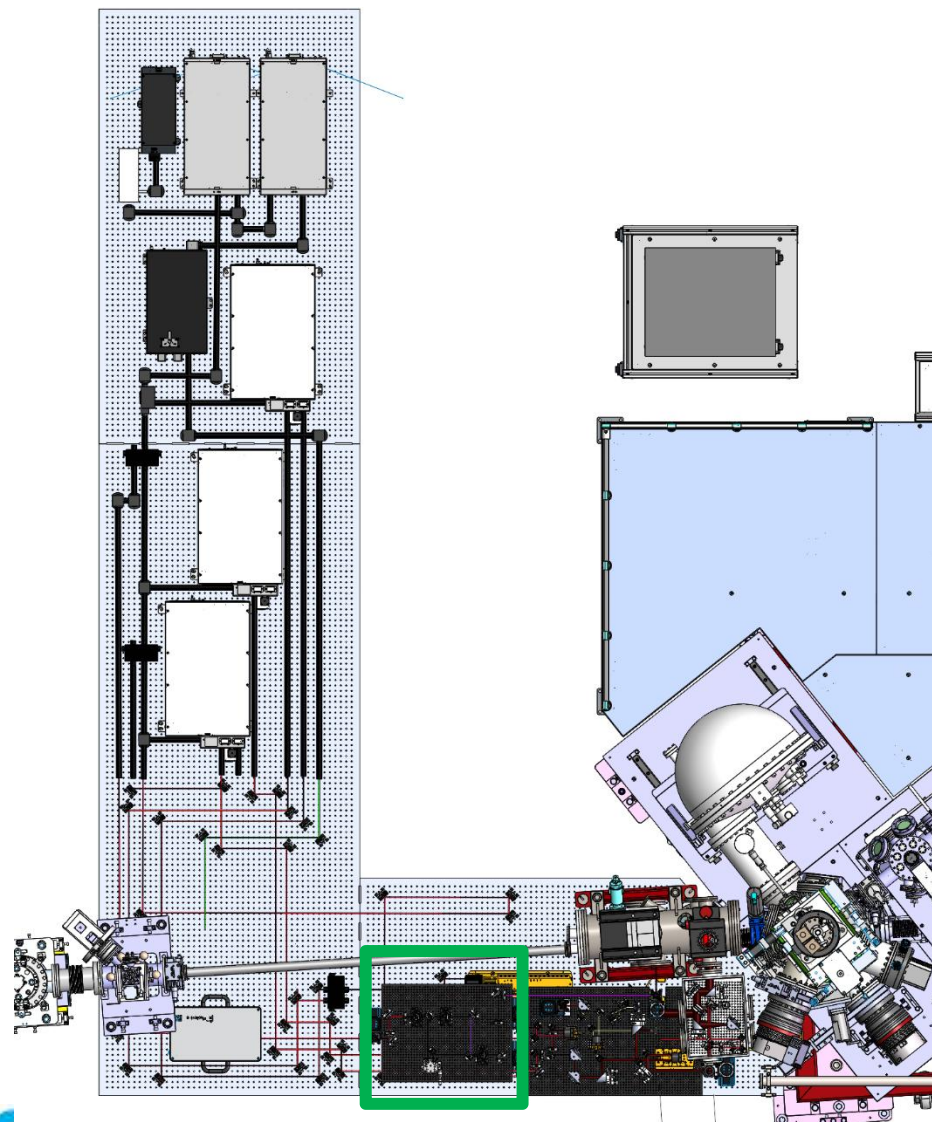
1200mm



Name	Model	Repetition rate	Pulse duration	Pulse energy	Power
Master CB3	Carbide	200 kHz	250 fs	145 µJ	29 W
Slave CB3	Carbide	200 kHz	250 fs	145 µJ	29 W
	Flint	60-100 MHz	100 fs	12.5 nJ	1 W

Name	Model	Repetition rate	Wavelength range
OPA-1	ORPHEUS-NEO-ONE	200 kHz	640 - 1000 nm, 1050 - 1350 nm 1350 - 2000 nm, 2100 - 4200 nm 4 - 16 µm (> 19 THz)
OPA-2	ORPHEUS-NEO-ONE	200 kHz	640 - 1000 nm, 1050 - 1350 nm 1350 - 2000 nm, 2100 - 4200 nm
OPA-3	ORPHEUS-NEO (SHG)	200 kHz	320 - 2600 nm

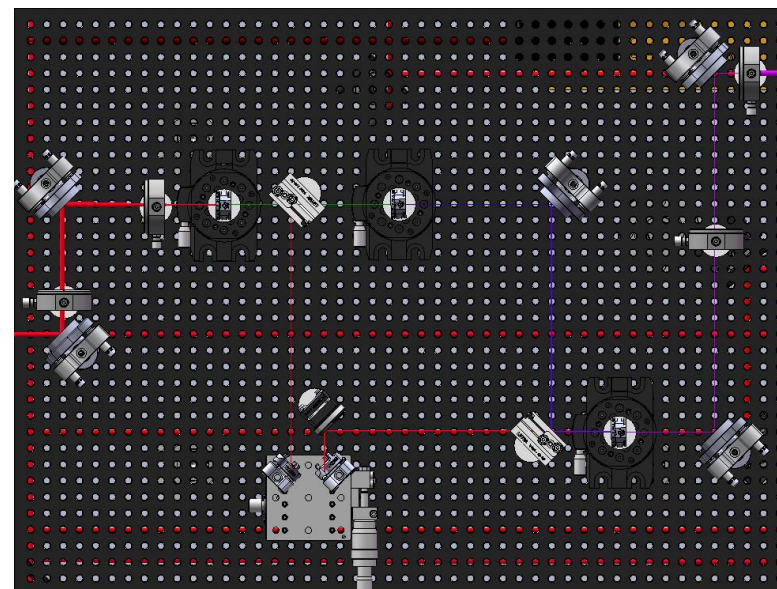
FiTH of 1030 nm



SHINE

Design parameters

Wavelength	Repetition rate	Pulse duration
~ 206 nm (~ 6 eV)	200 kHz	< 60 fs

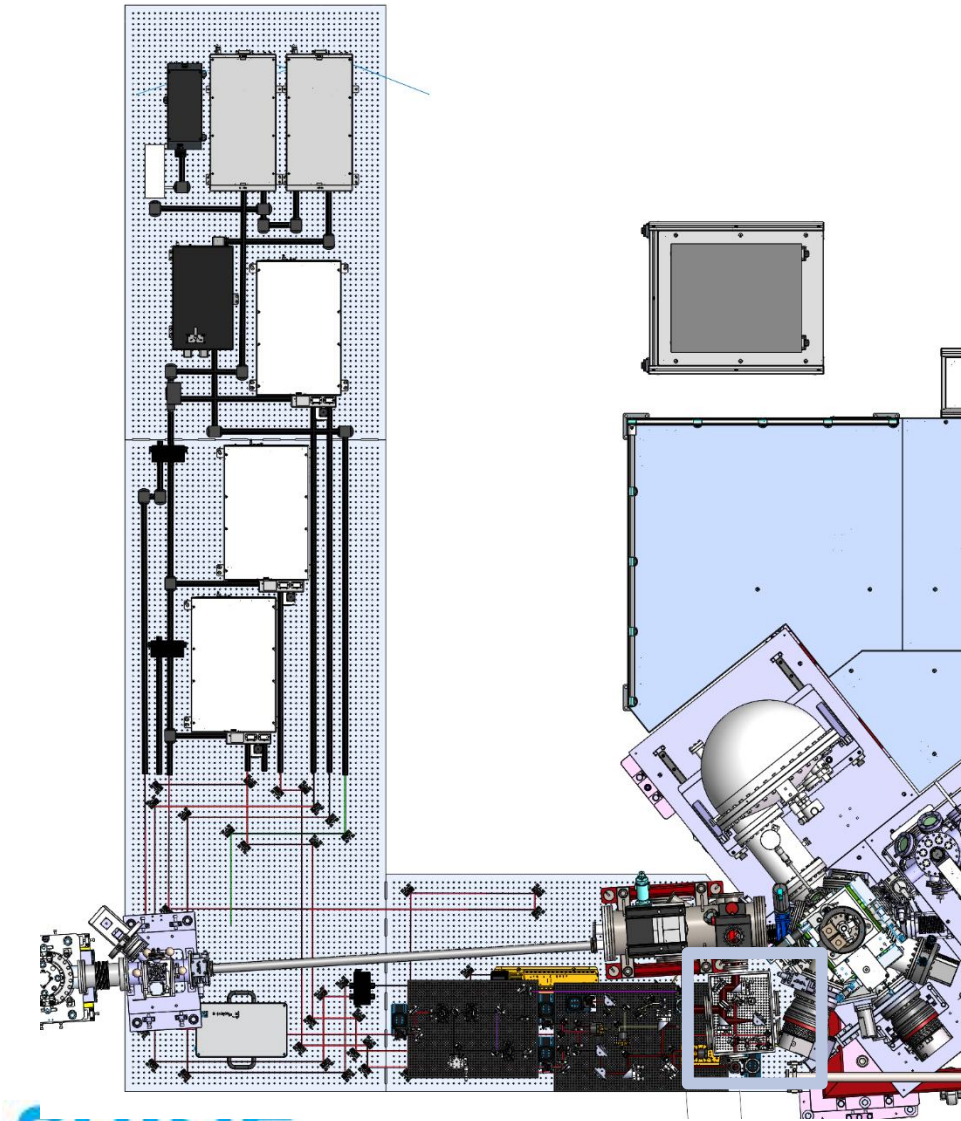


Optical Rectification – OR-THz

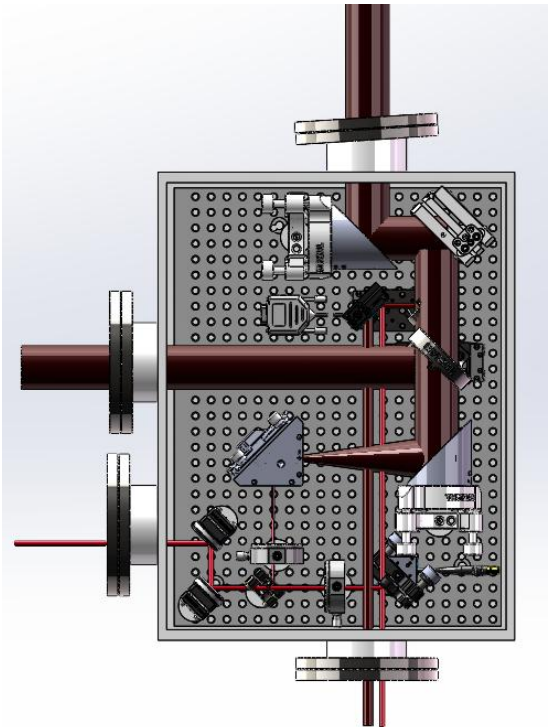


Estimated performance

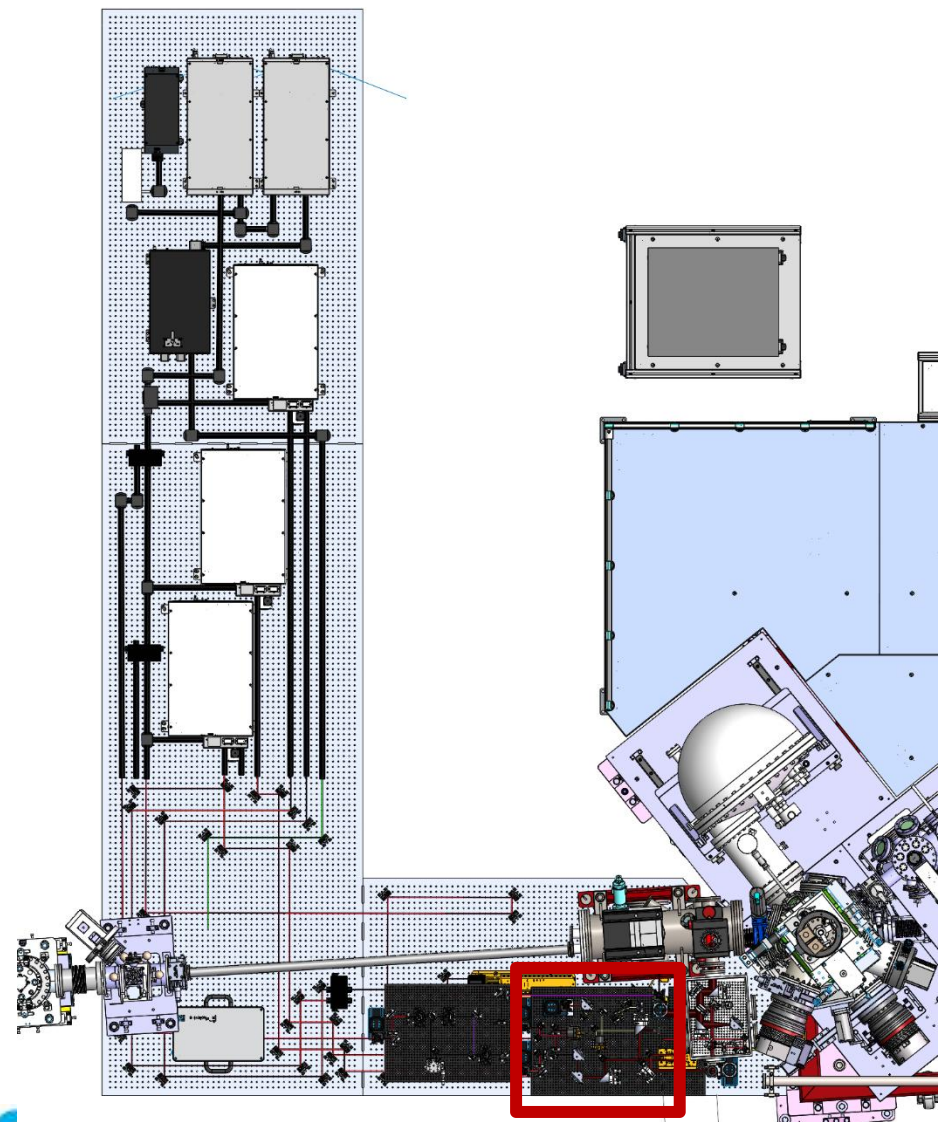
THz range	Repetition rate	Electric field	Crystal
1-4 THz	200 kHz	> 100 KV/cm@2 mm (spot size)	BNA (cooling)
1-4 THz	200 kHz	> 200 KV/cm@2 mm (spot size)	ZGP



SHINE



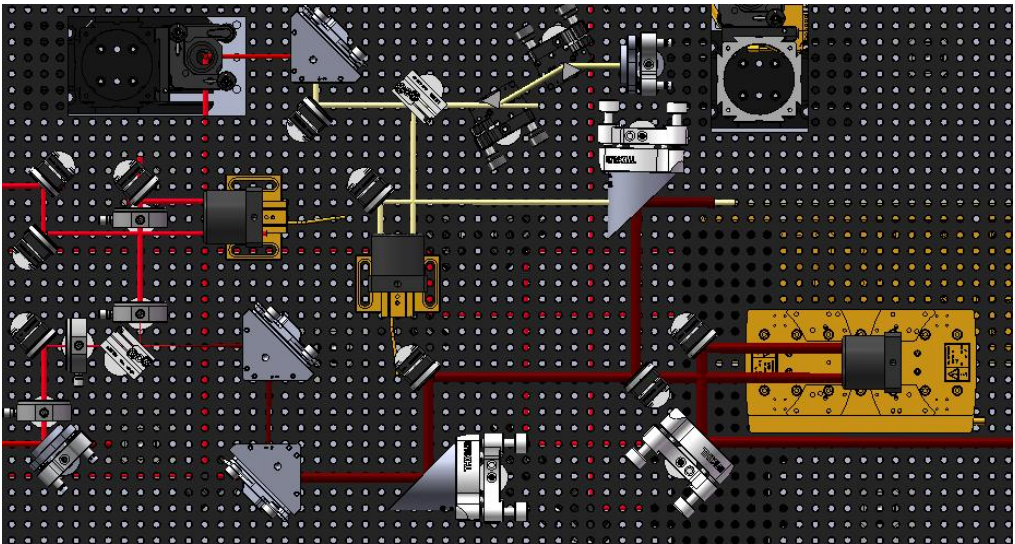
Difference Frequency Generation – DFG-THz



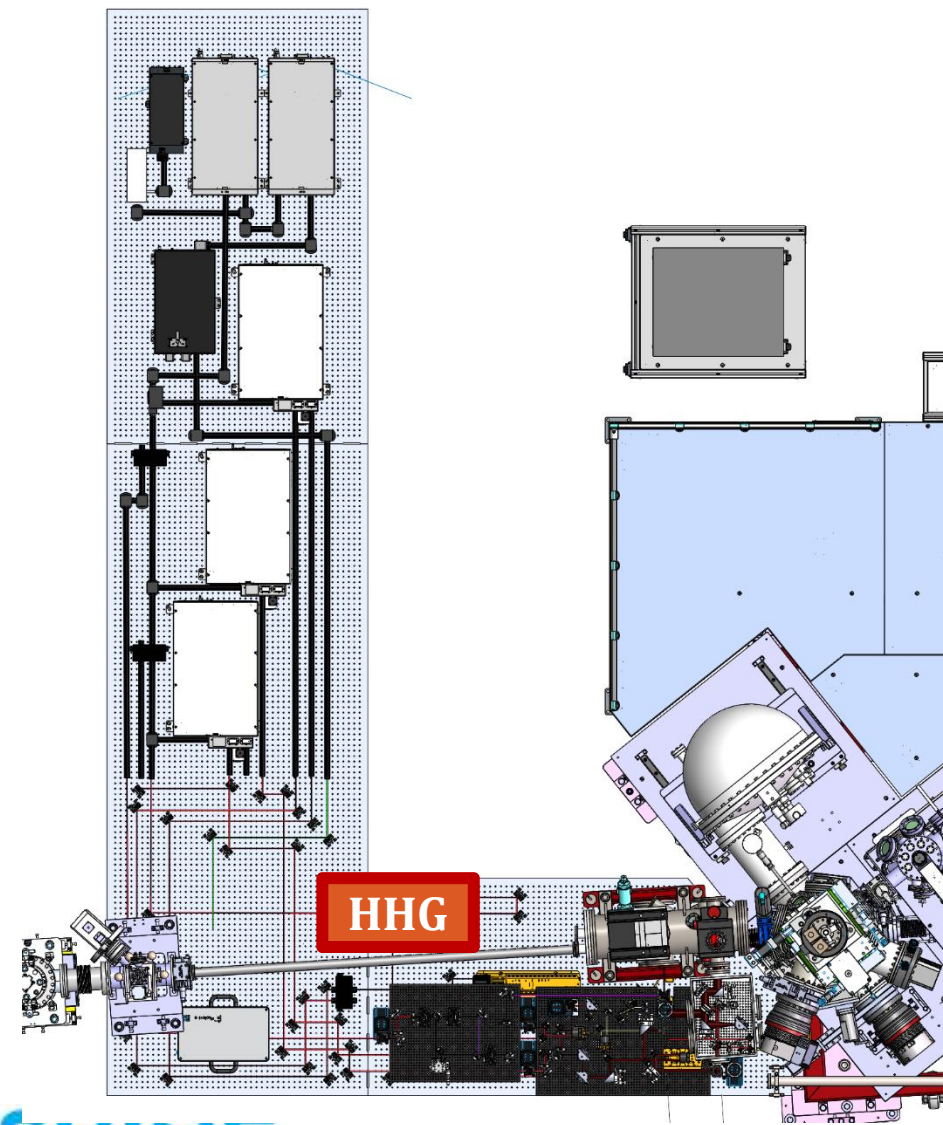
SHINE

Estimated performance

THz range	Repetition rate	Electric field	Crystal
12-42 THz	200 kHz	> 100 KV/cm@500 μm (spot size)	GaSe
4-18	200 kHz	> 100 KV/cm@500 μm (spot size)	Organic crystal (cooling)

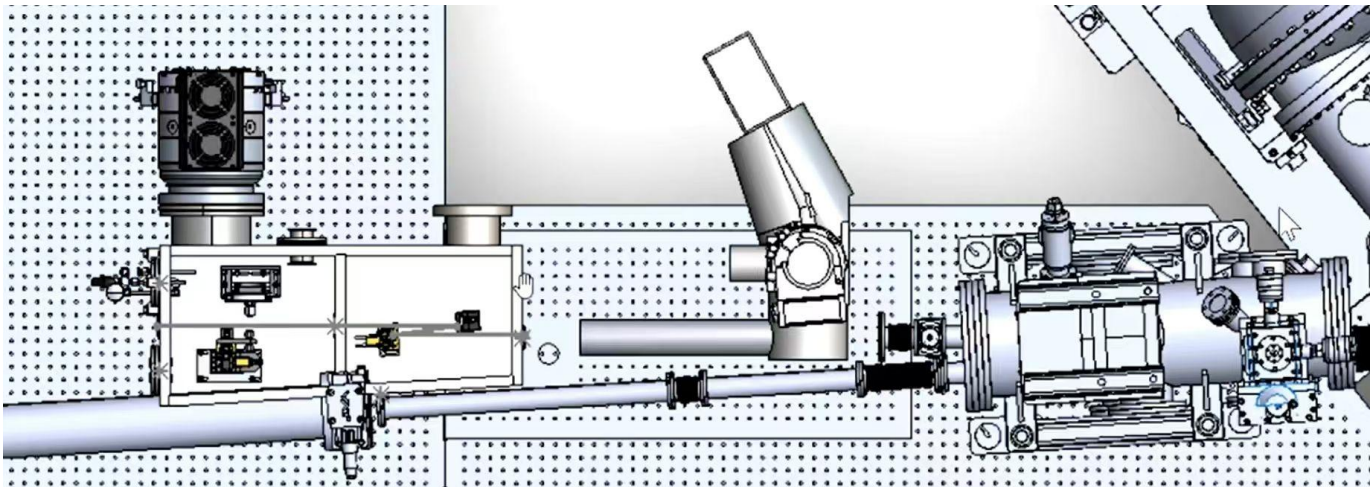


High Harmonic Generation (HHG) from AFS Jena

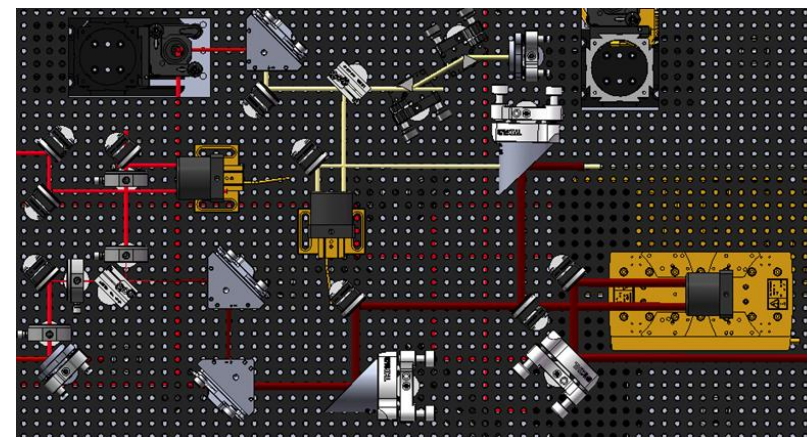
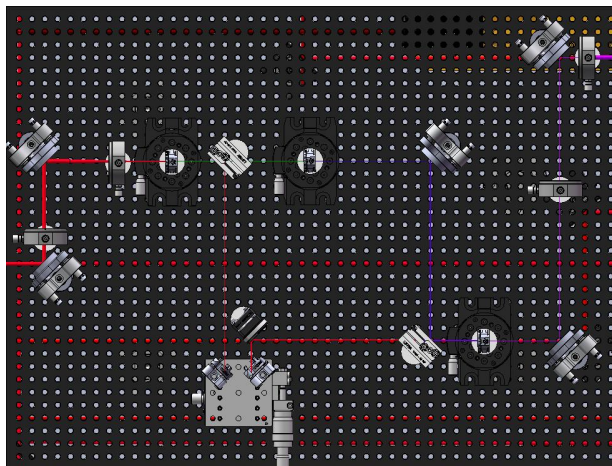


Design parameters

Photon Energy	Repetition rate	Pulse duration	Energy resolution	Pulse intensity	Focusing beam size
26.6 eV	200 kHz	< 150 fs	150 meV	2E+10 photon/s @ focusing point	< 150 μm



Timeline of LC carbide driving Laser systems



Laser

2027.01

LC carbide Arrival Date:

2026.11.28

FiTH

2027.04

OR-THz

2027.06

DFG-THz

2027.07

HHG 26.6eV

2027.10

