Progress of FEL-AMO Endstation

Speaker: Xincheng Wang

On behalf of AMO Group

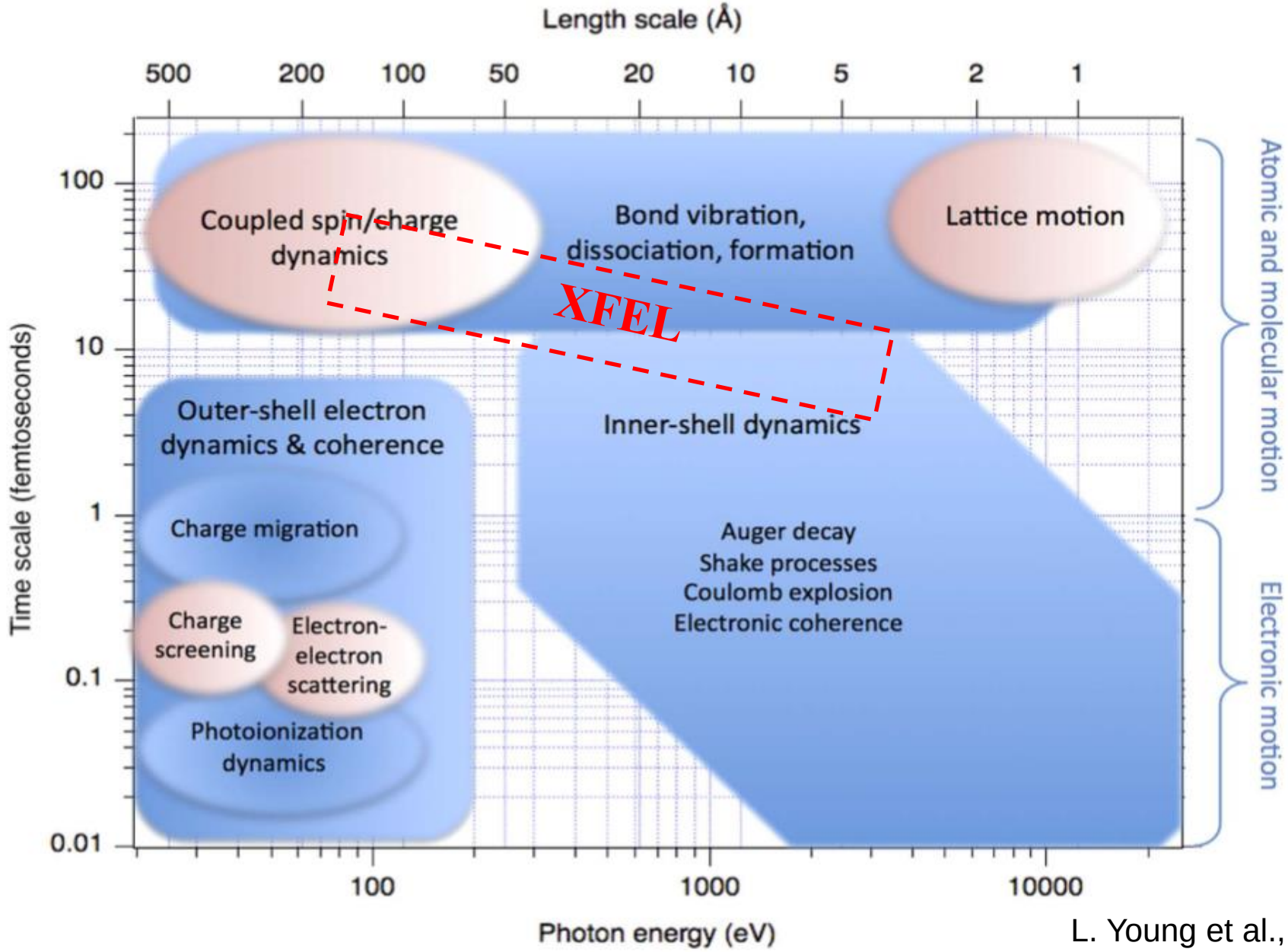
Oct. 22, 2025

SHINE

Outline

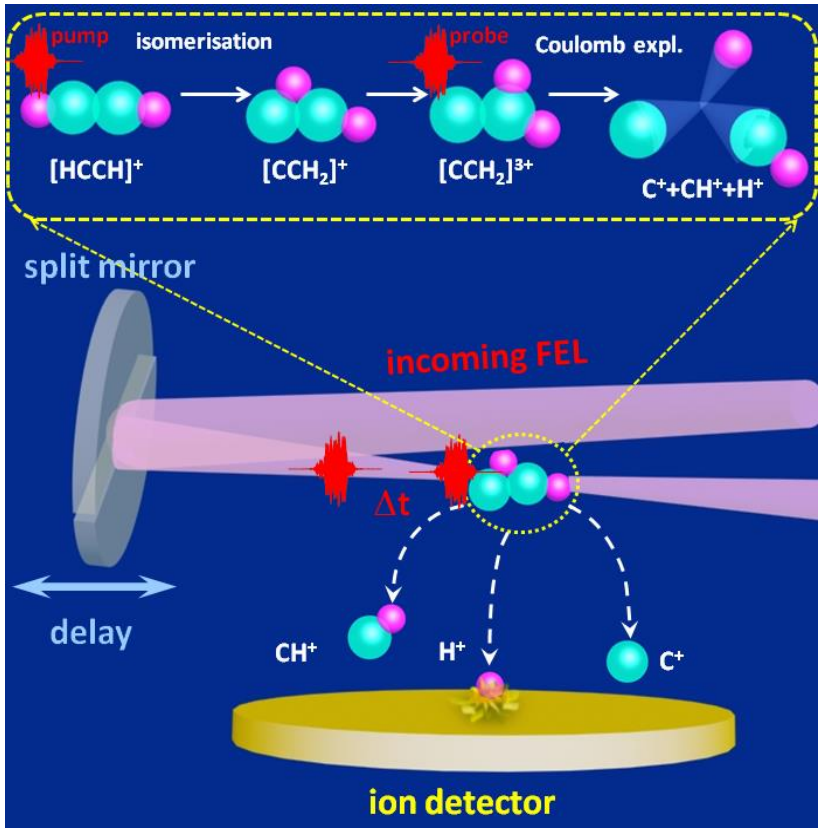
- AMO Science with FELs
- AMO Endstation @ Shine
- Commissioning plans

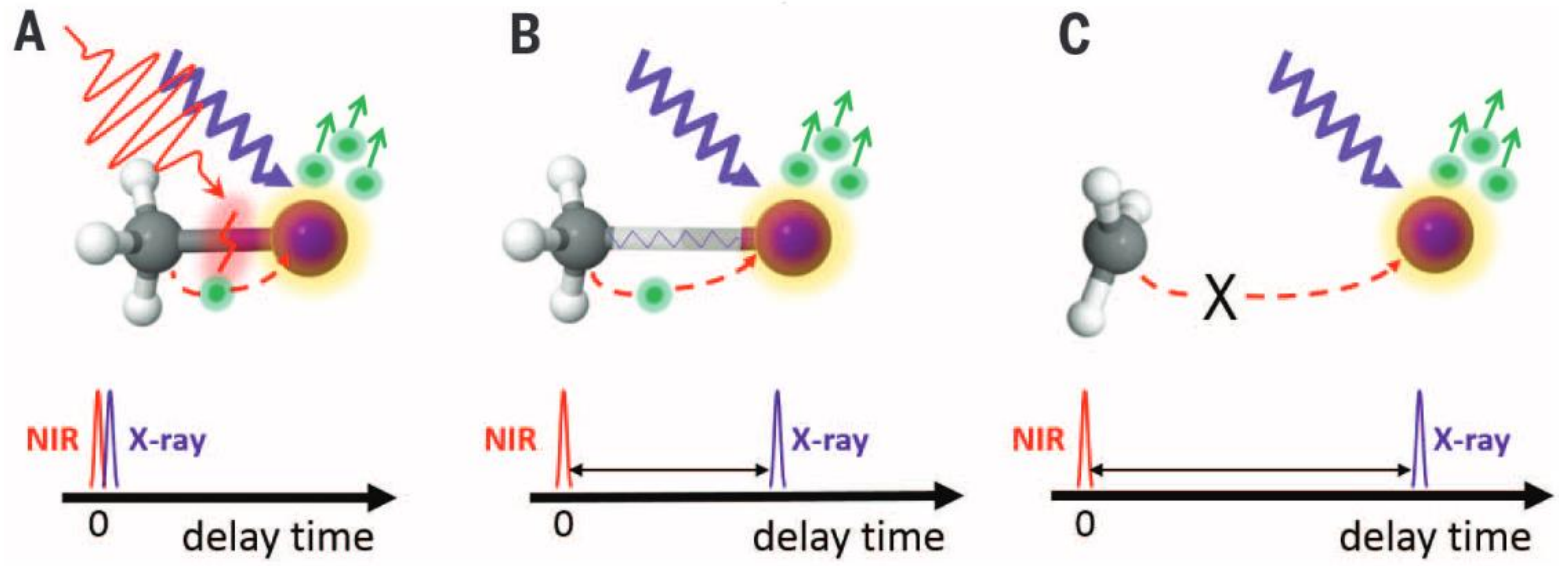
AMO Science with FELs



L. Young et al., JPB 51, 032003 (2018)

AMO Science with FELs





Jiang et al., Phys. Rev. Lett. **105**, 263002 (2010)

Erk et al., Science **345**, 288 (2014)

Time-resolved investigations of structural and electronic dynamics

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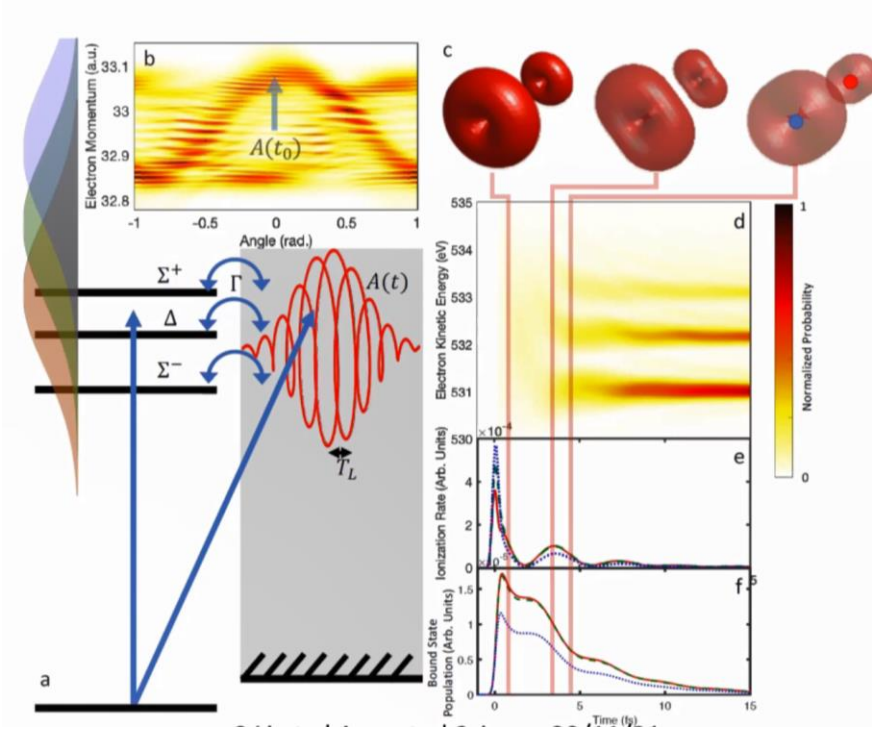
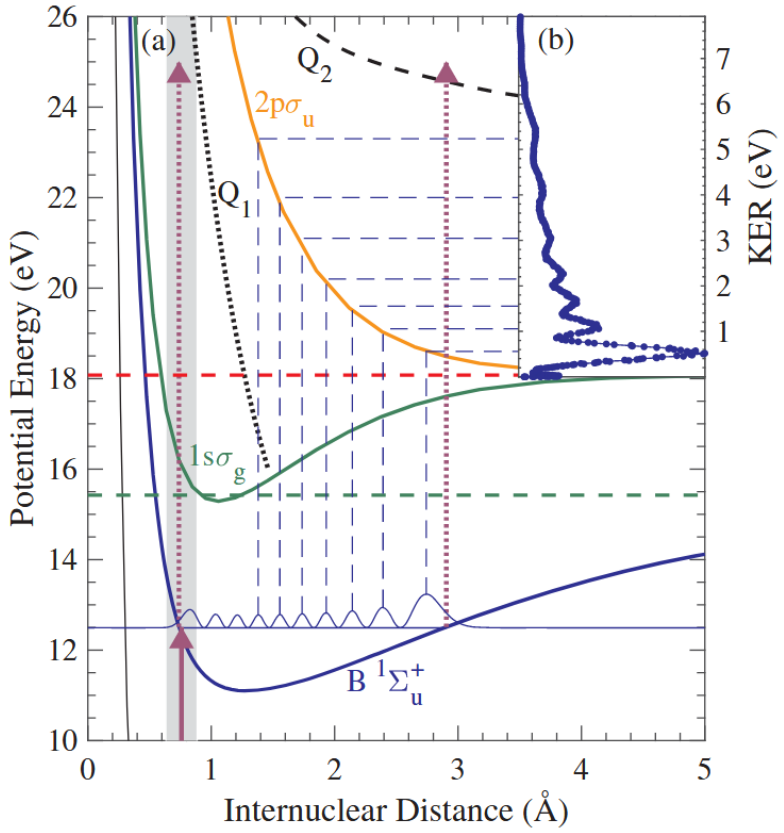
AMO Science with FELs



Li et al., Science **375**, 285 (2022)



Holzmeier et al.,
Phys. Rev. Lett. **121**, 103002 (2018)

Coherent controlled studies of structural and electronic dynamics

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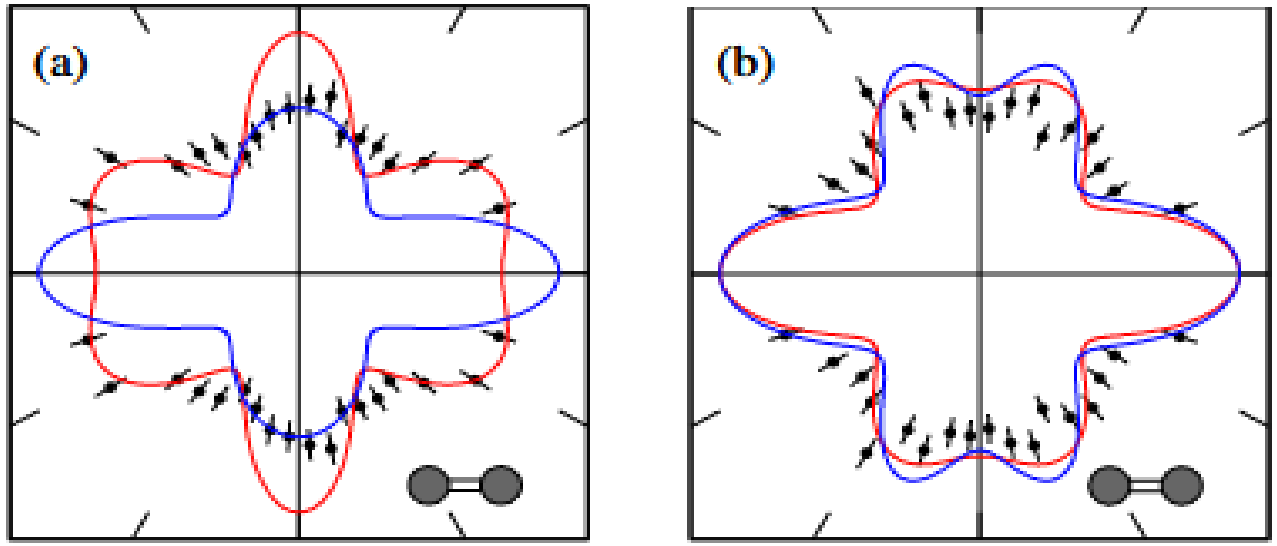
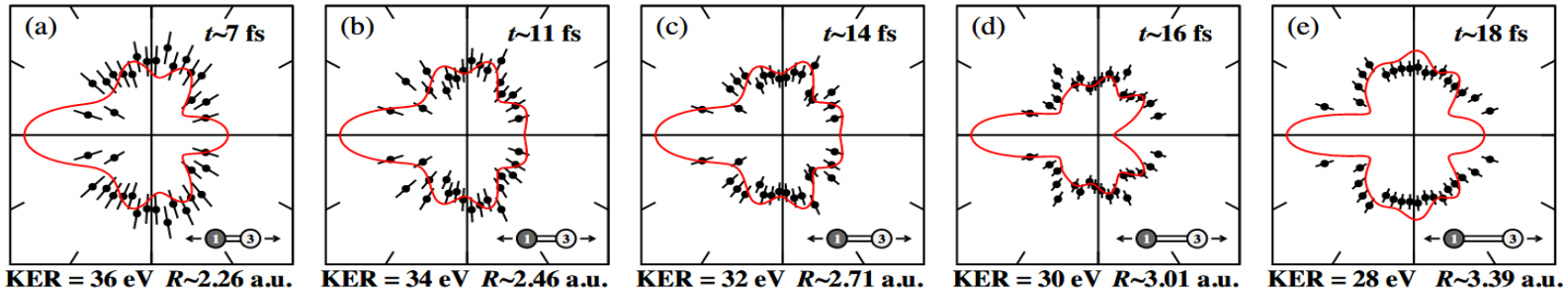
AMO Science with FELs





Kastirke et al., PRL 125, 163201 (2020)
Kastirke et al., PRX 10, 021052 (2020)

SHINE **Molecular-frame photoelectron angular distributions**

Outlines

- AMO Science with FELs
- **AMO Endstation @ Shine**
- Commissioning plans

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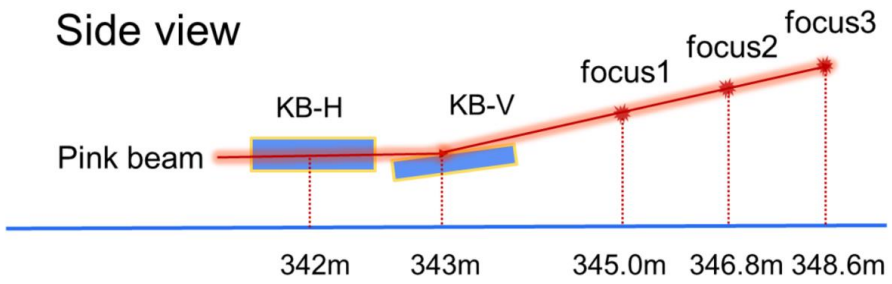
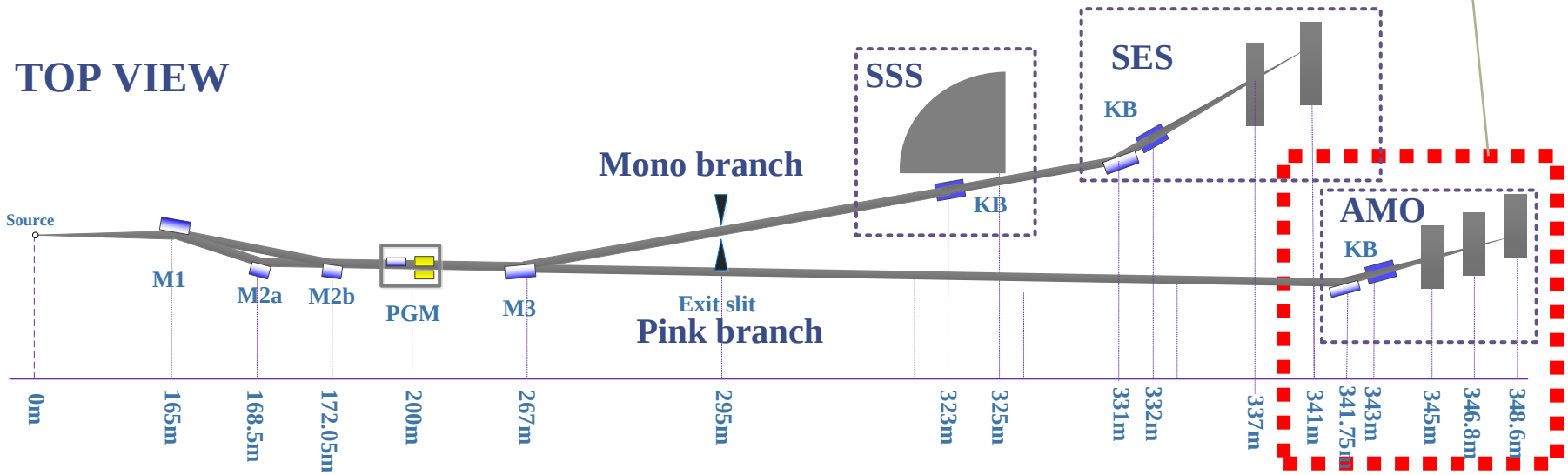
FEL2 Beam-line Layout

- SSS: Soft X-ray Scattering and Spectroscopy Endstation
- SES: Spectrometer for Electronic Structure, material science
- IEB：Diffraction Imaging Branch for Biology Coherent control
- AMO: atomic and molecular science





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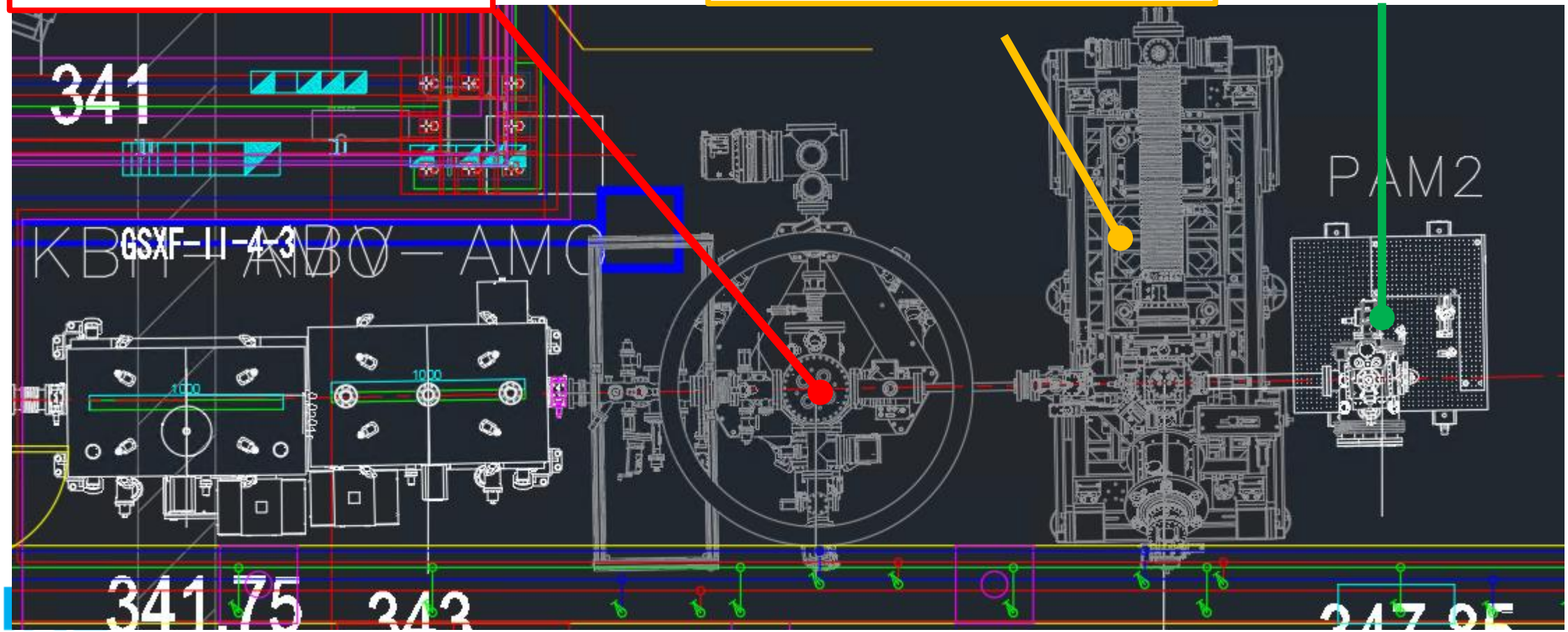
AMO endstation at SHINE

Three foci

COLTRIMS:
Coincident electron and ion measurements

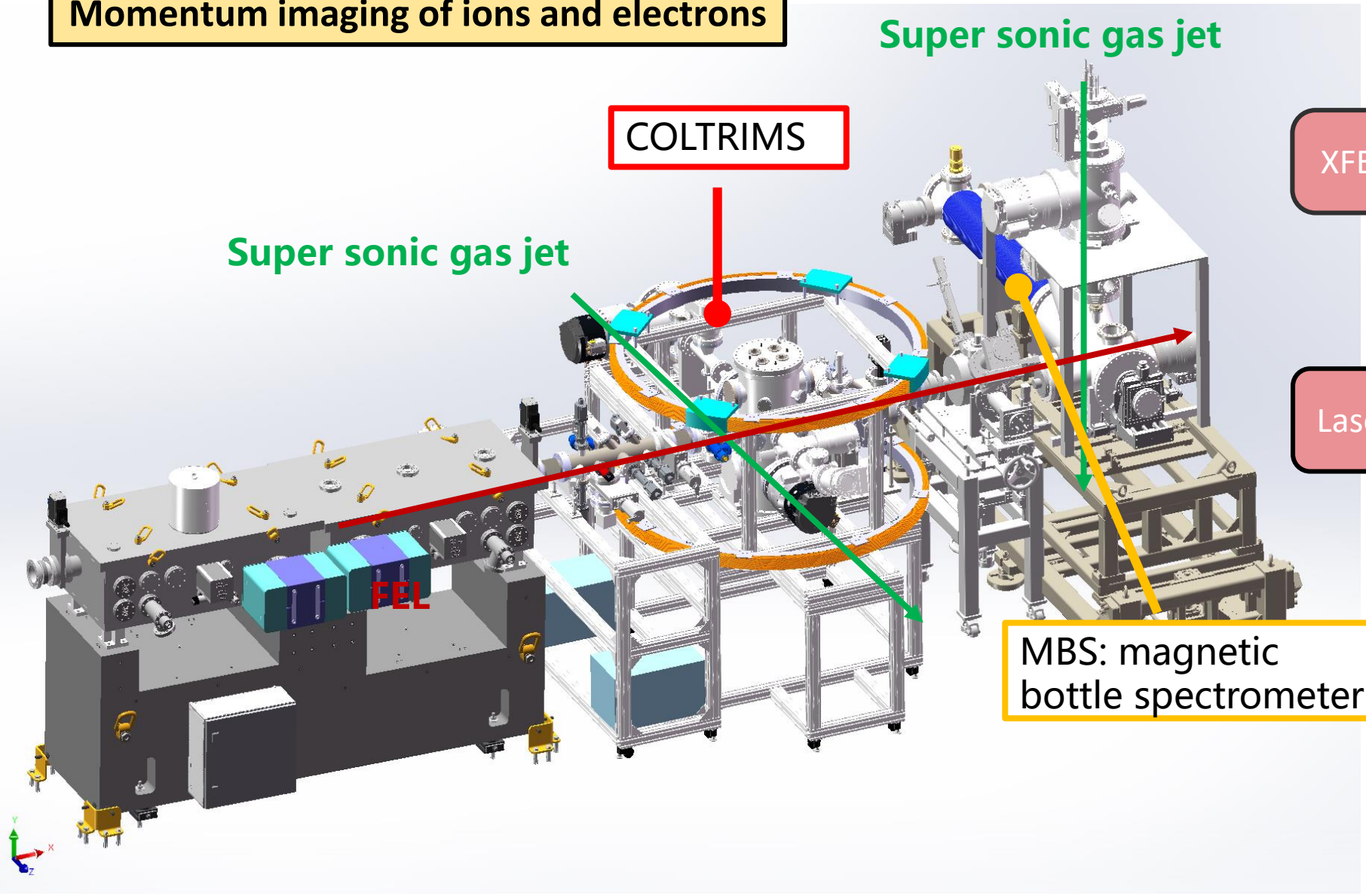
eMBS/iTOF:
High-resolution electron spectra/ion TOF spectroscopy

TM diagnostic of pulse/PIPO



AMO endstation at SHINE

Momentum imaging of ions and electrons



Experimental parameters:

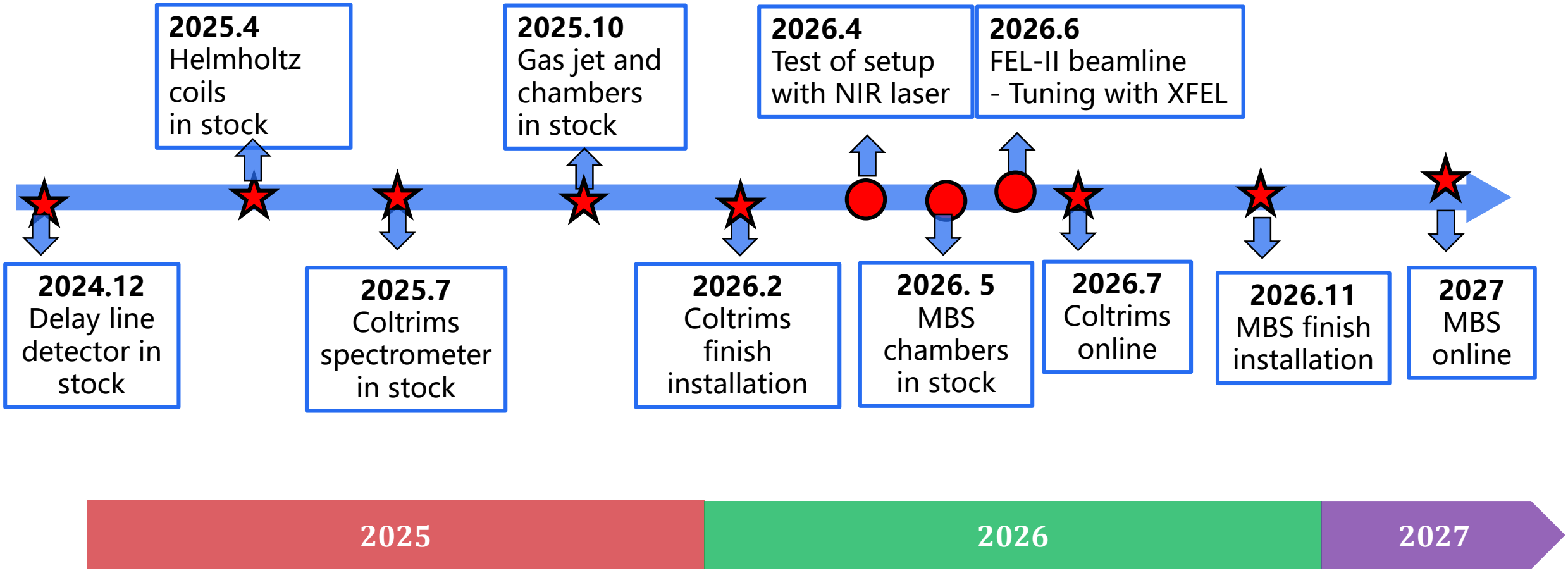
XFEL
- Energy range： 0.2~3 keV
- Beam spot size: < 10 um
- Pulse duration: 10 ~ 150 fs
- Jitter: < 35 fs
- Repetition rate: 100 kHz
- Pulse energy: 10-300 uJ

Laser
- Wavelength: 266-3000 nm
- Repetition rate: 100 kHz
- Spot size: <100 um
- Pulse energy: >100 uJ @fundamental
- Pulse duration: 30 ~ 150 fs

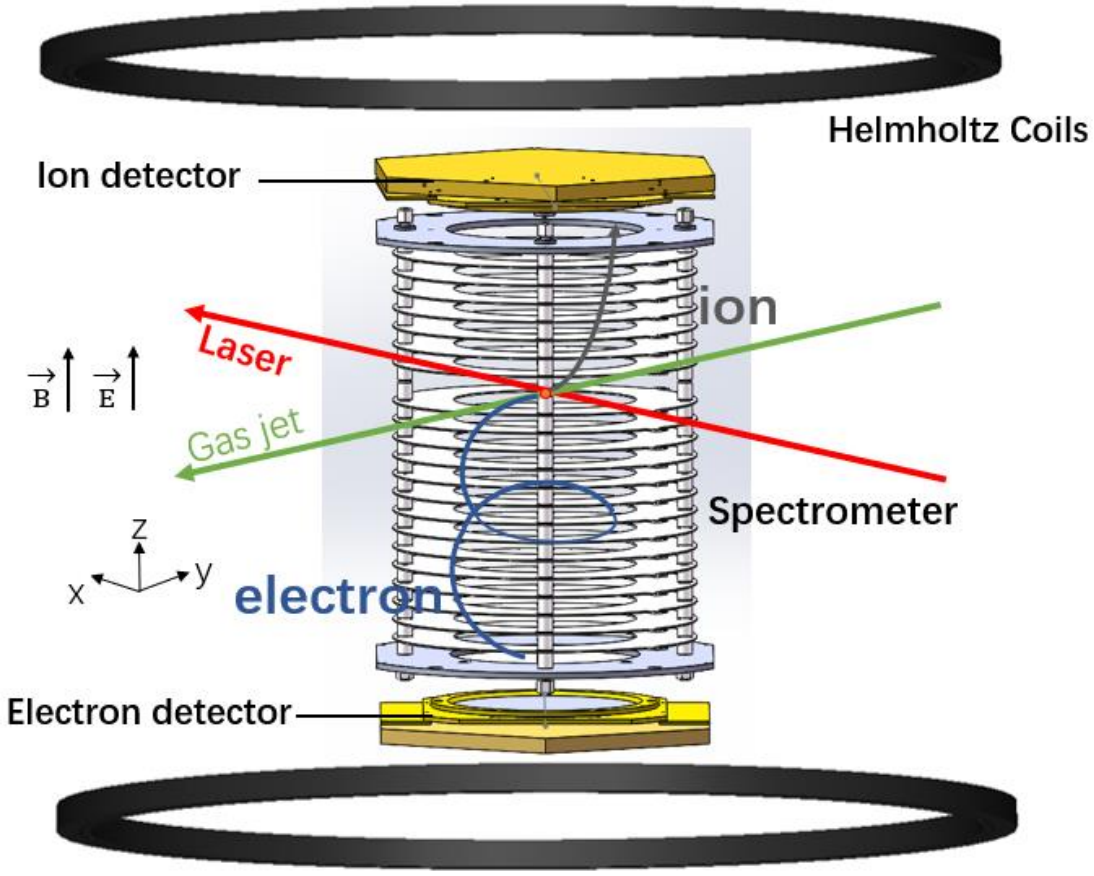
diagnostic tools:

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

CPM plan of AMO Endstation



COLTRIMS



MCP: t_z –> Pz

Delayline: t_x, t_y –> x, y –> Px, Py

Spectrometer:

- meV resolution for ions
- meV for electrons

- base pressure 10^{-11} mbar
- fast detector readout (Multi-channels, 1 GHz)

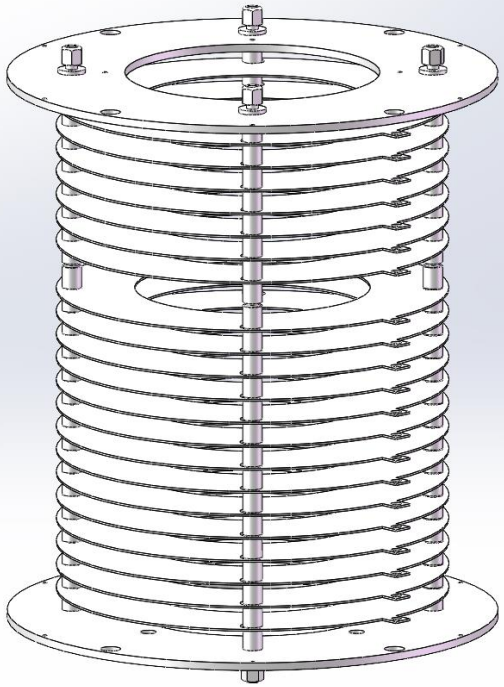
- Target density: 10^{8} – 10^{11} cm^{-3}
- Target temper.: 100 mK

Character:

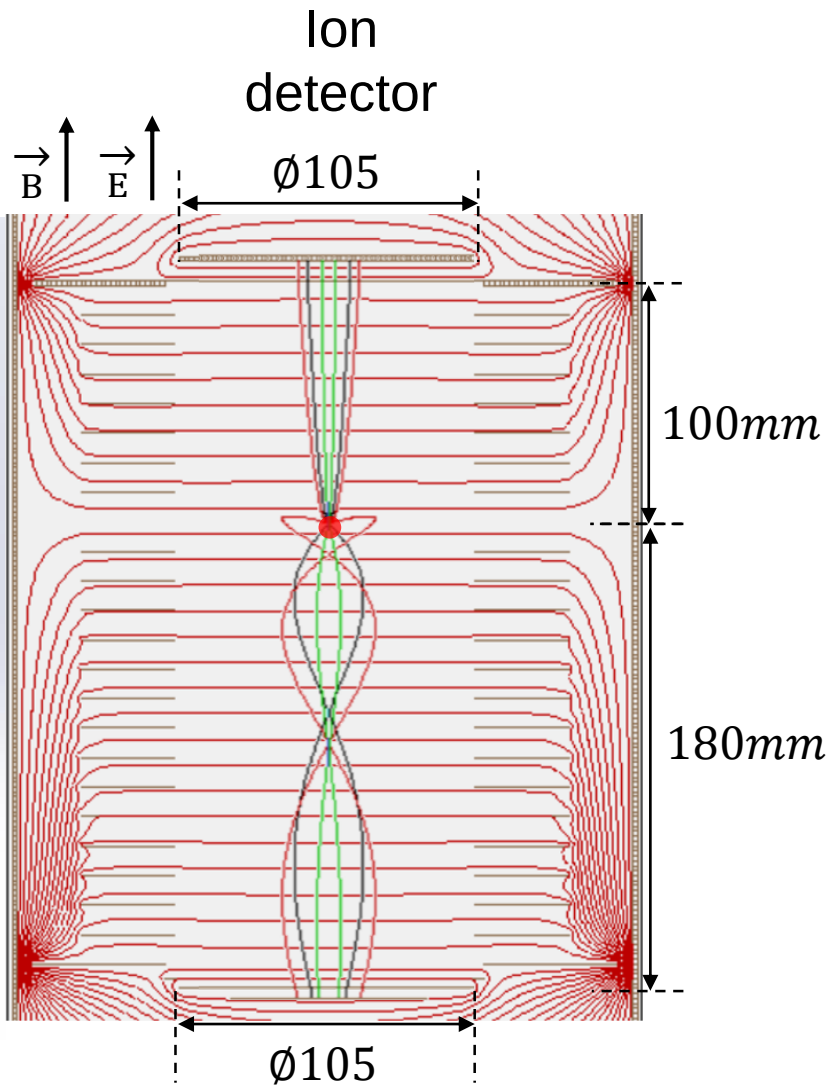
- Supersonic jet for gas phase and volatile targets
- 4π electron and ion imaging
- Electron and ion in coincidence

COLTRIMS

Spectrometer:



Spectrometer structure



Electron
detector

- Uniform electric/magnetic field.
  - 0-200 V/cm
  - 0-20 G

- Results:

  4π Solid angle for electrons up to 300 eV
  for O^+ up to 10 eV

  Resolution: ions: ~1%
  electrons: ~1%

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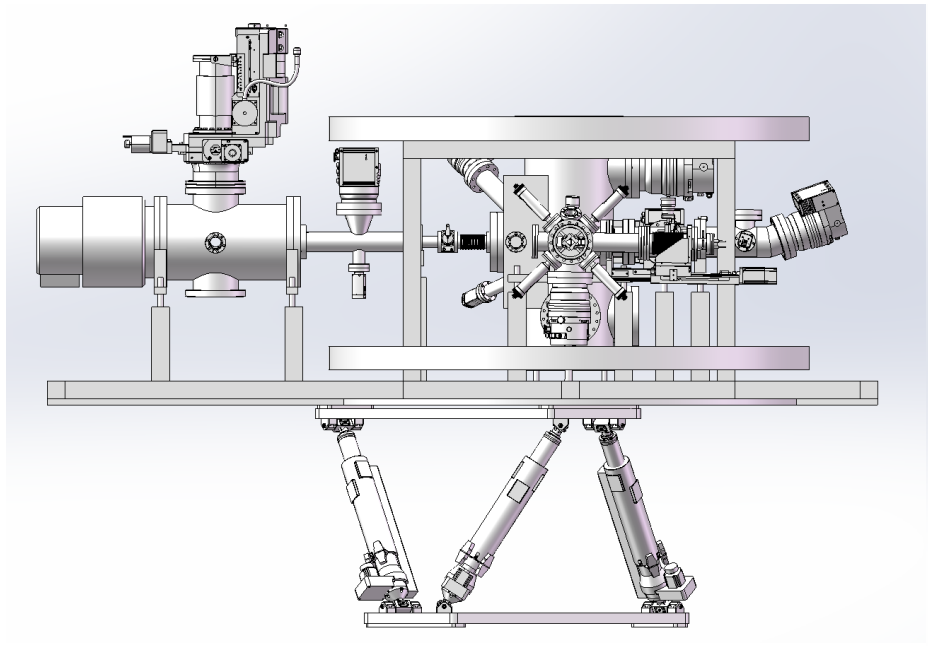
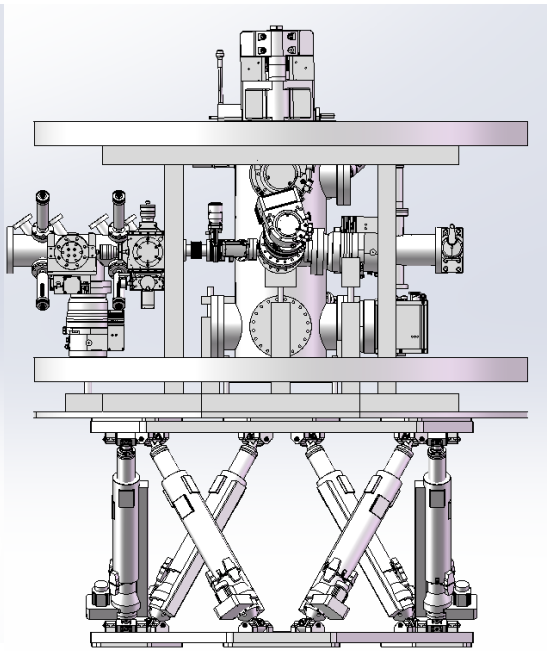
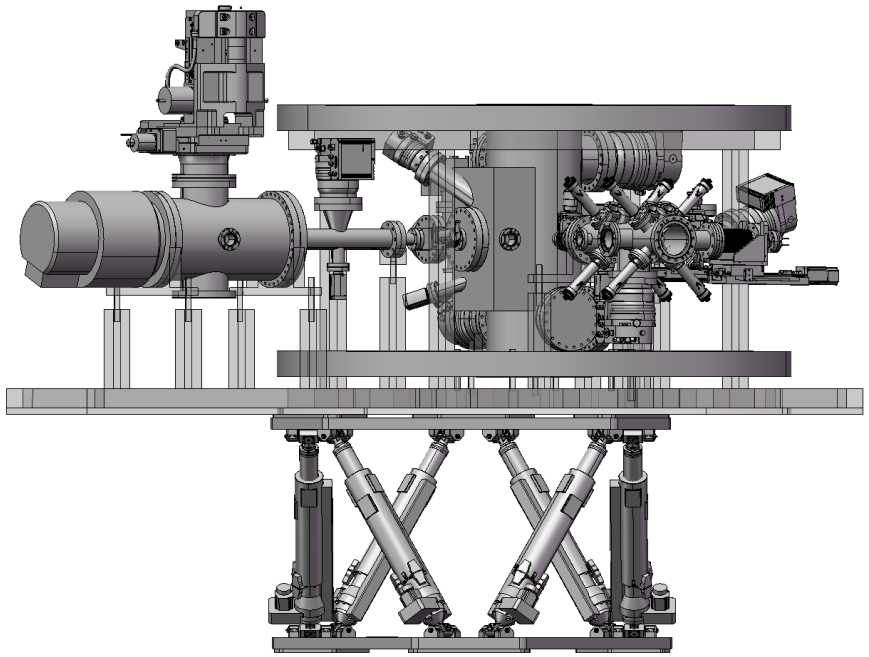
COLTRIMS







The acceptance indexes of the mechanical control system:

- The maximum load capacity of the mechanical support: 1500 kg
- The translational distance: ±50mm
- The translational accuracy: 1μm
- The return difference: 5μm
- The rotational angle: ±1 °, the rotational accuracy: 0.001 °, and the return difference: 0.005 °

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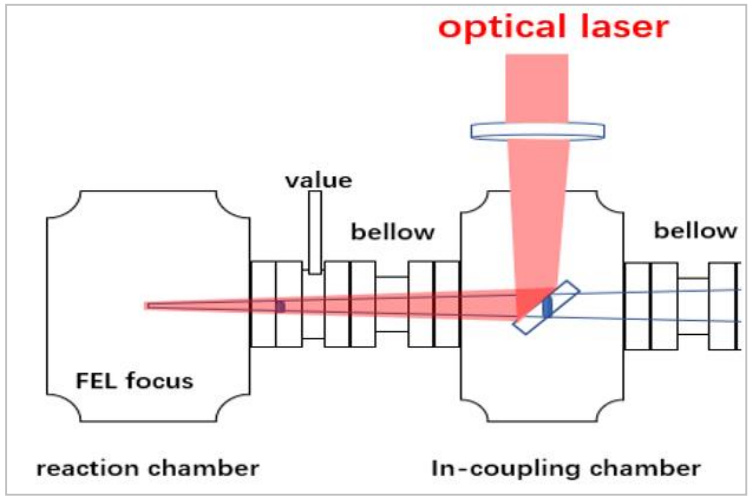
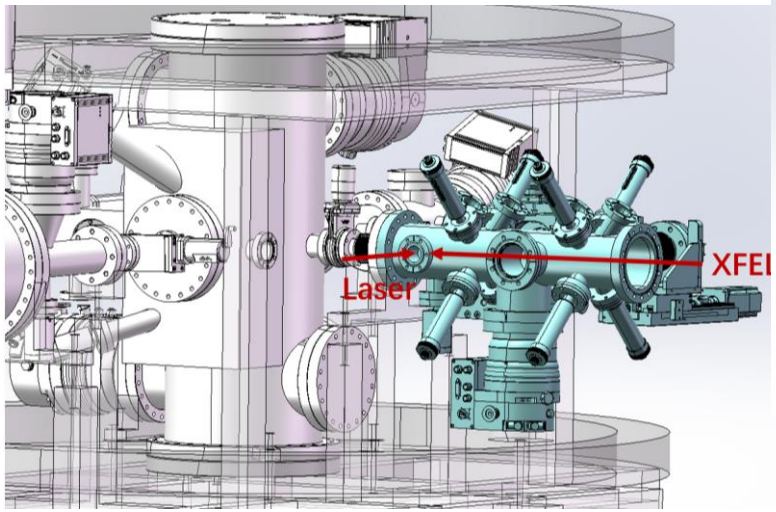
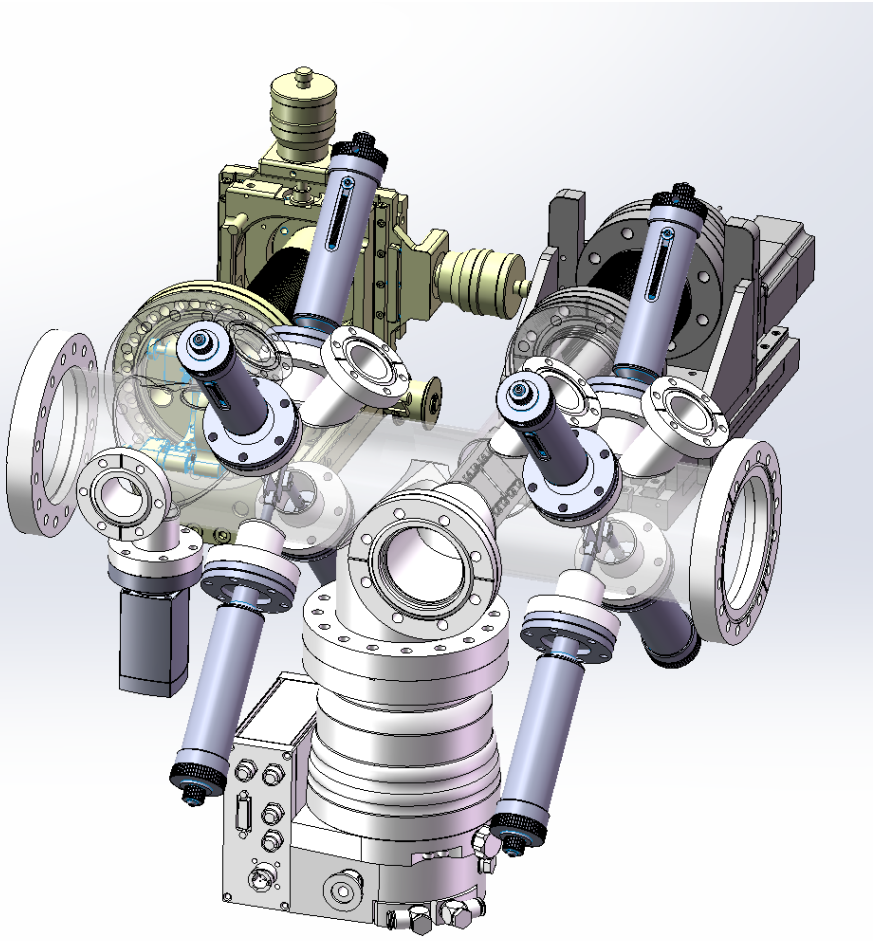
Optical Beamline

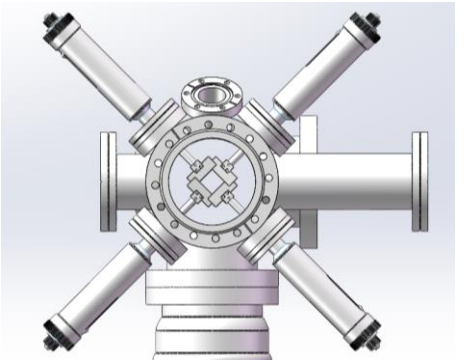
Laser incoupling chamber



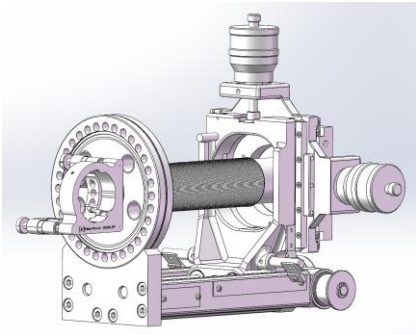




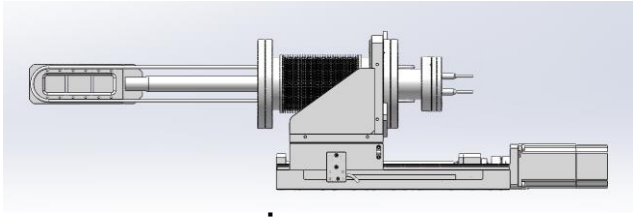
key components in the optical beamline



Slit

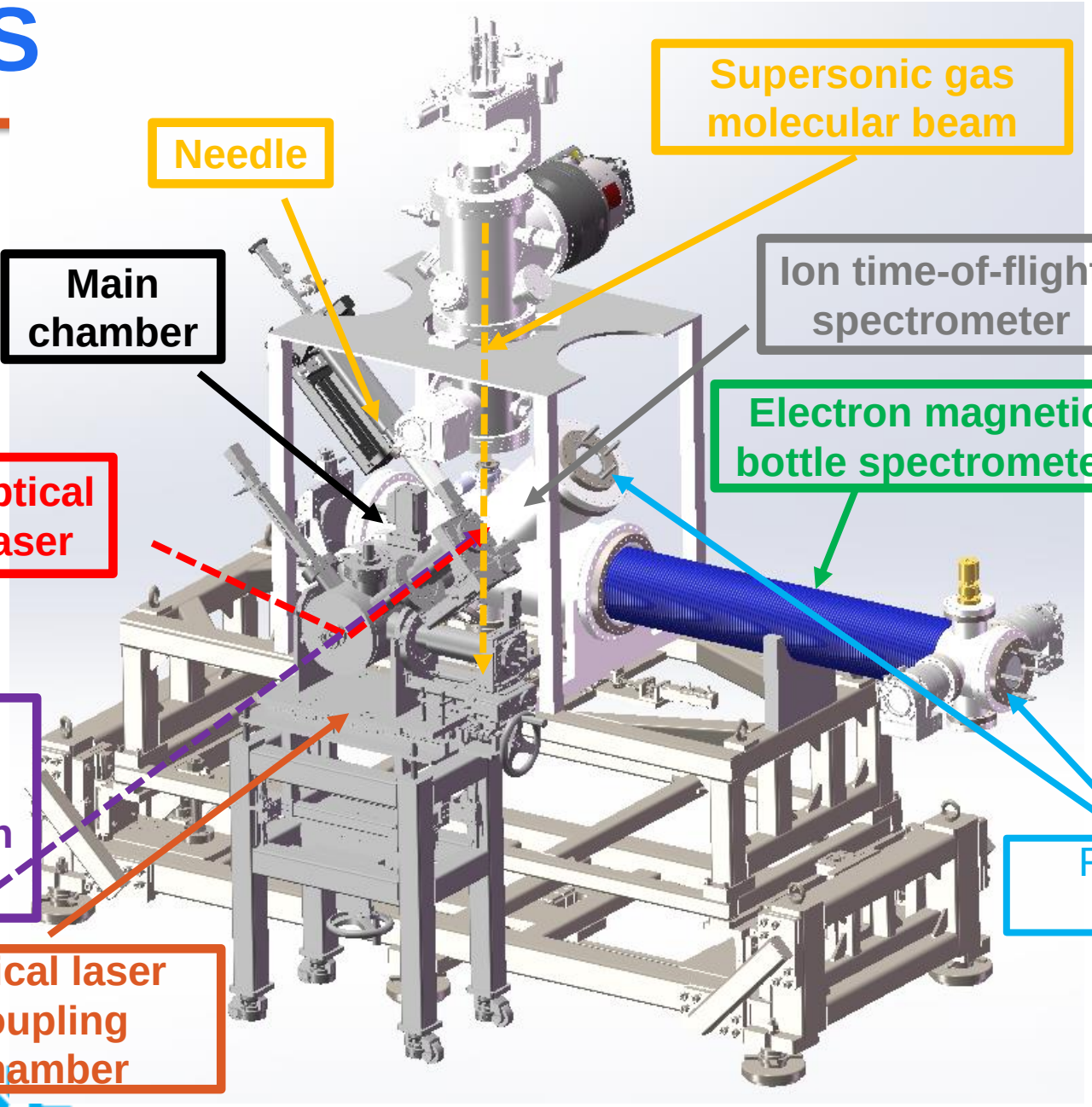


Reflective mirror



imager

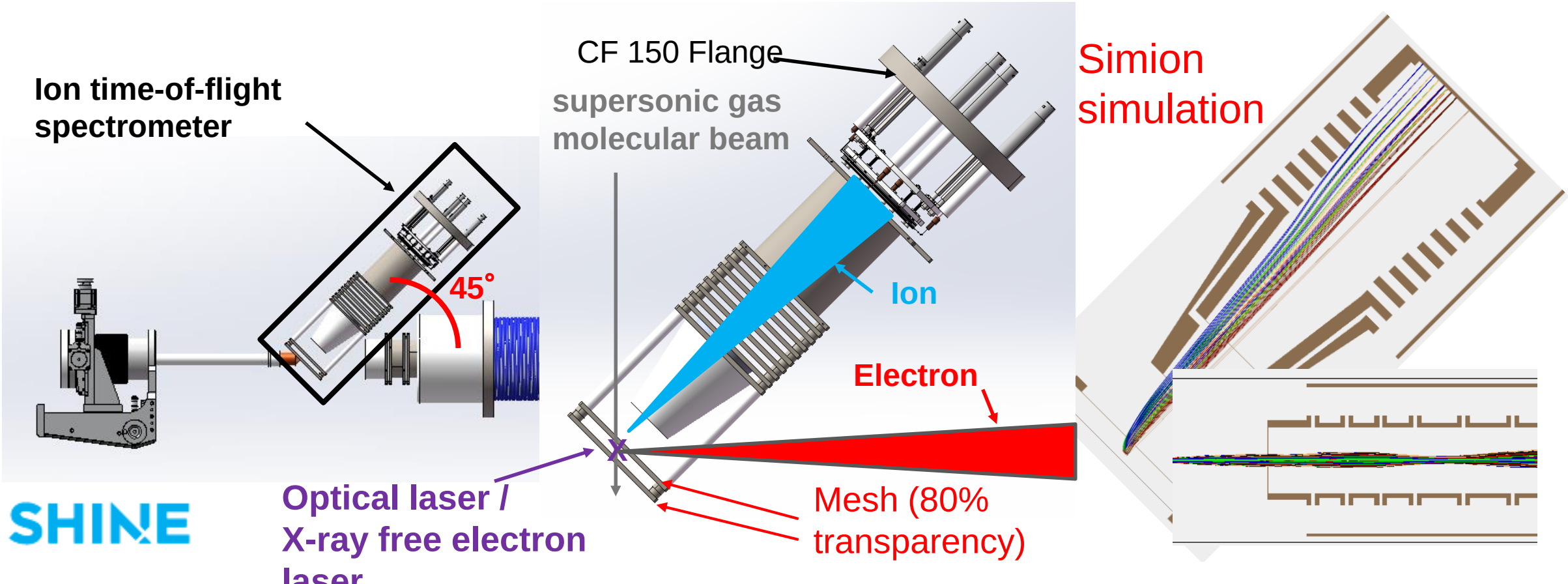
MBS



- Main chamber
- Optical laser coupling chamber
- Supersonic jet & needle
- Electron magnetic bottle spectrometer
- Ion time-of-flight spectrometer

MBS

The ion time-of-flight spectrometer is used to obtain the ion charge-mass ratio information, which is at a 45° with the Electron magnetic bottle spectrometer, and the supersonic molecular beam reacts with light through the mesh in the reaction region.



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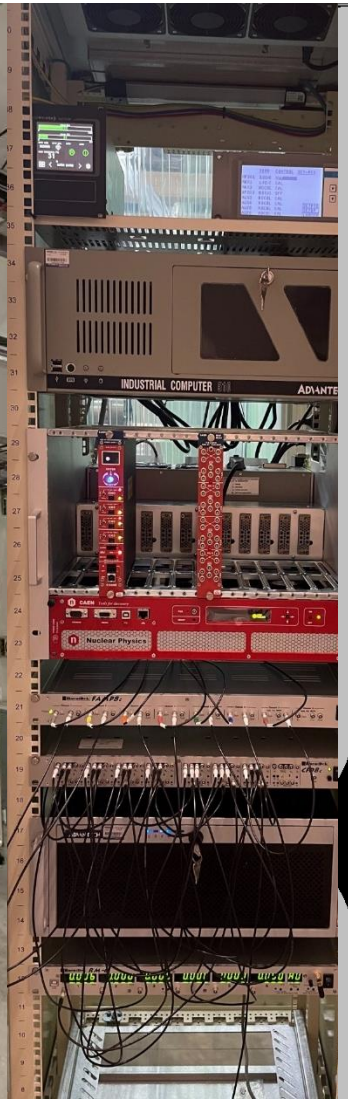
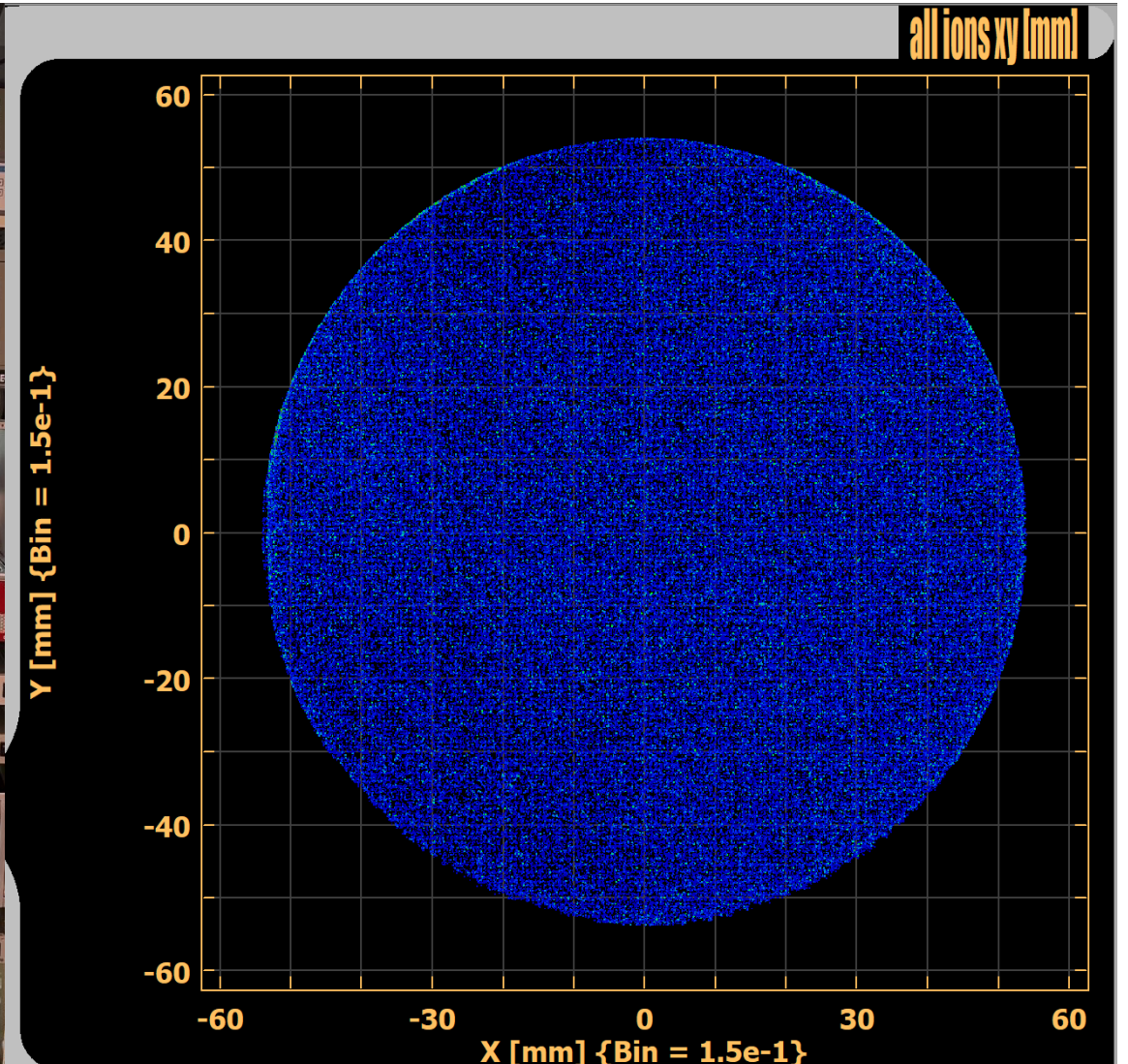
Current status





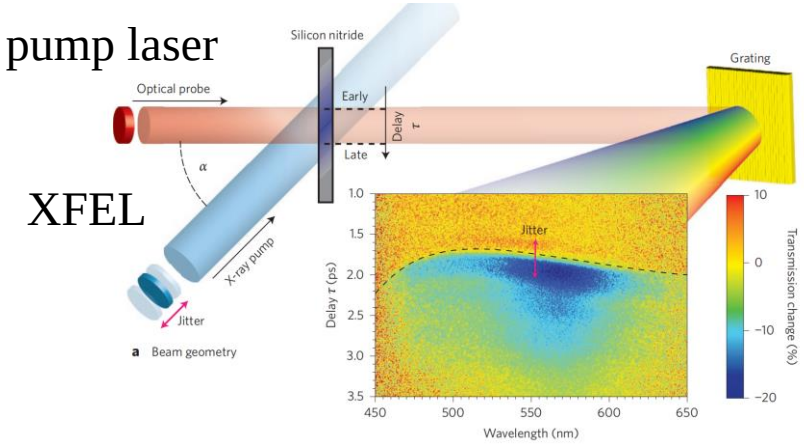
Photon Arrival Time Monitor (PAM)

The photon arrival time monitor contributes to the arrival time diagnose between the XFEL pulse and laser pulse in the pump-probe experiment basing on the spectral/spatial encoding method.

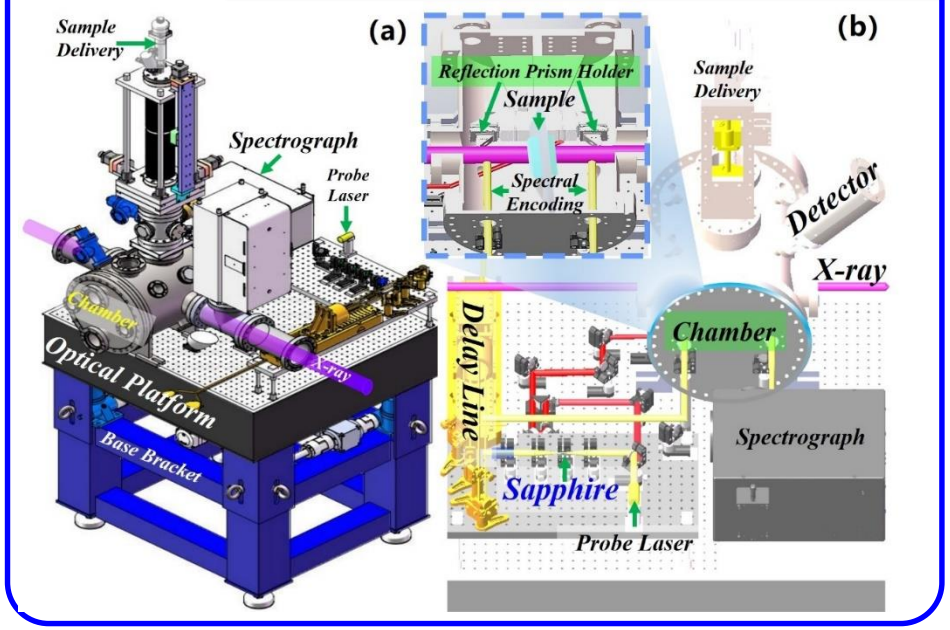
Designing goal ：**accuracy<15 fs (RMS)**

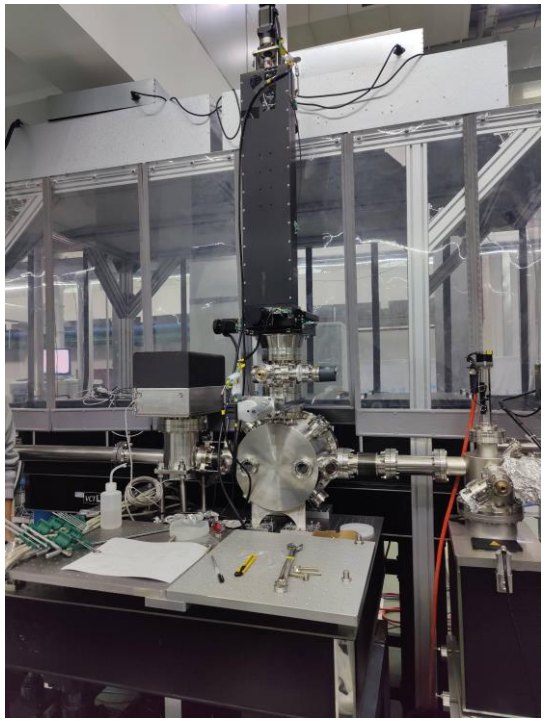
provided by **diagnosis Group** in SHINE

Spectral/spatial encoding



optical layout and equipment





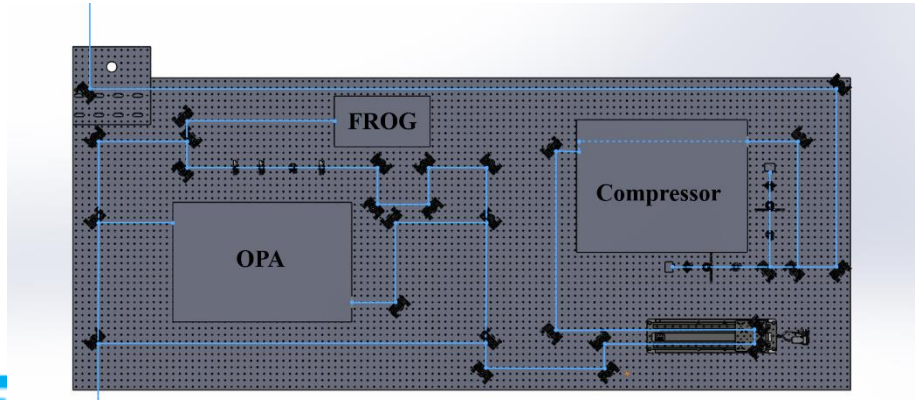
Pump-probe Laser system for AMO

Laser available

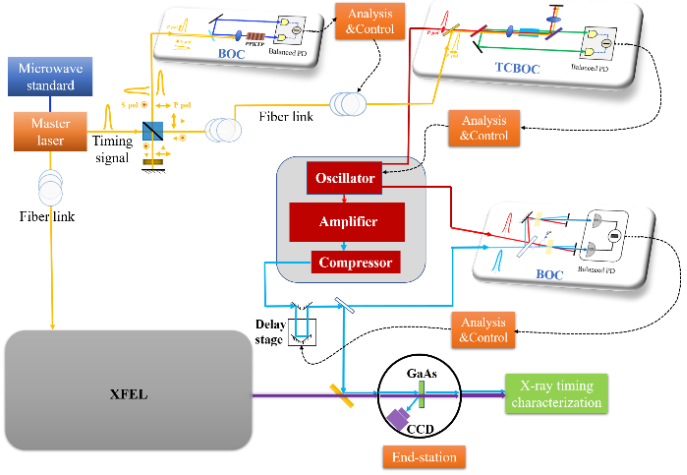
- ✓ Low repetition rate laser (working at first stage-low repetition rate of XFEL): **800 nm, 35 fs, 7 mJ, 1 kHz**
- ✓ High repetition rate and high-power laser: **1030 nm, 25~40 fs, 100 W @100 kHz**
- ✓ **Uncompressed** fundamental laser pulse transported through **evacuated tubes** and **re-compressed** at end-station
- ✓ Frequency conversion units: UV to IR by OPA; Harmonic Generator (SHG/THG)

Synchronization between pump-probe laser and XFEL

- ✓ Oscillator locked to the master laser and timing drift between oscillator and amplifier will be further compensated
- ✓ < **40 fs jitter** between pump-probe laser and XFEL pulse can be achieved



Optical design of pump-probe laser at AMO end-station



Synchronization between pump-probe laser and XFEL

*Pump-probe laser system is provided by **Laser Group** in SHINE

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- AMO Endstation @ Shine
- **Commissioning plans**

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FEL Parameters for commissioning

FEL Parameters	T0	T0 +5 months	T0 +10 months
FEL MODE	SASE	SASE	SASE
Photon energy (eV)	200	100,200	100~200
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

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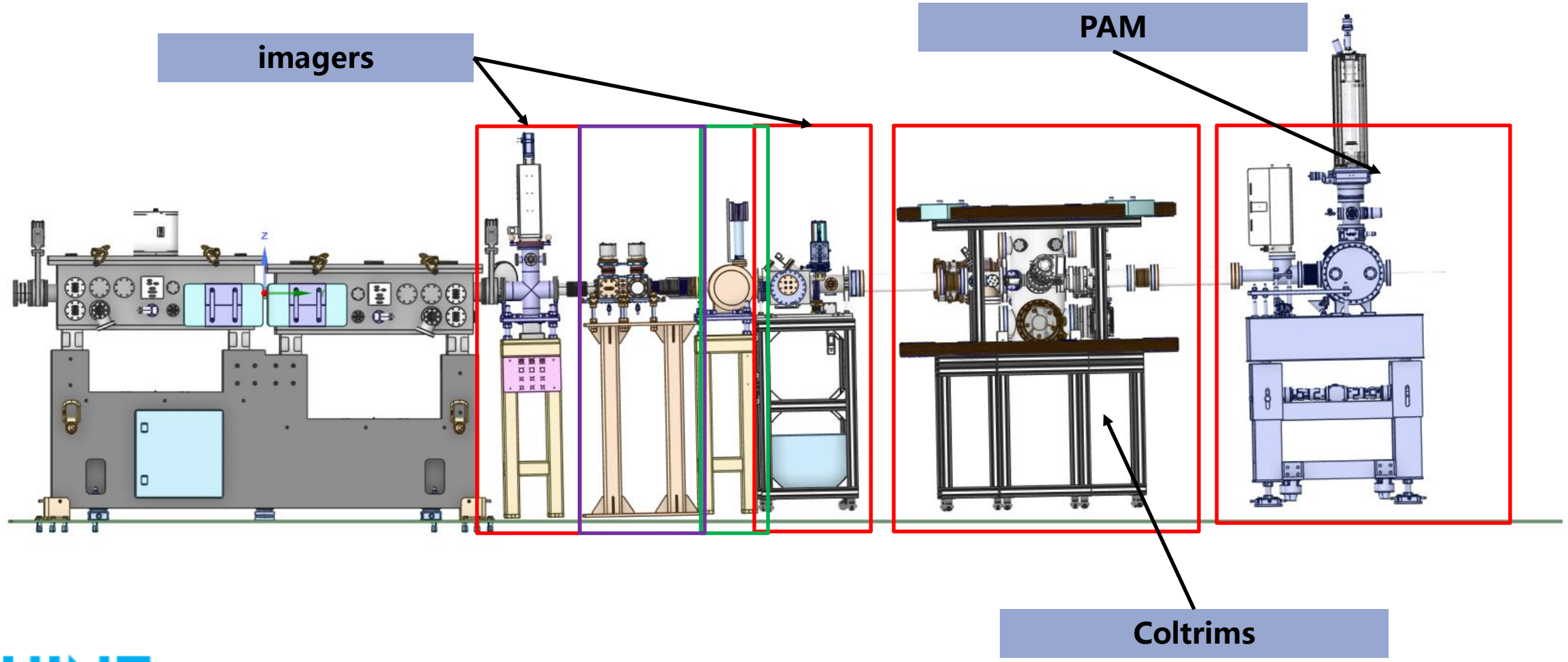
✓ Based on the photon energy, the commissioning will be focus on Ne Ne_2 O_2

Layout for the commissioning



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Acknowledgement

AMO team:

Yunfei Feng, Jianfeng Liao, Mingjie Zhang, Kefei Wu, Yikang Zhang, Hailong Guo, Jinze Feng, Jianye Huang, Wentao Zhu, Ruicao Dong, XiuRan Zhu, Jianfei Tao,

Zhenjie Shen, Yuhai Jiang, Kiyoshi Ueda, Xiaojing Liu, Xincheng Wang

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Thank you for your attention!

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