Current status of experimental platforms with high-power lasers at SACLA

Kohei Miyanishi on behalf of SACLA
SACLA
10th March 2021
Breakout sessions A2: High-power Optical Lasers

High-power laser systems available for combinative use with hard X-ray FELs at SACLA

SACLA XFEL

Laser compression Exp. Platform (Experimental Hutch 5 on Beamline 3)

Y. Inubushi et al., Appl. Sci. 10, 2224 (2020).

High-power Nanosecond Laser

Osaka Univ.

Hamamatsu Photonics

OSAKA UNIVERSITY

HED Exp. Platform (Experimental Hutch 6 on Beamline 2)

T. Yabuuchi et al., J. Synchrotron Rad. 26, 585 (2019).

High-power femtosecond Laser

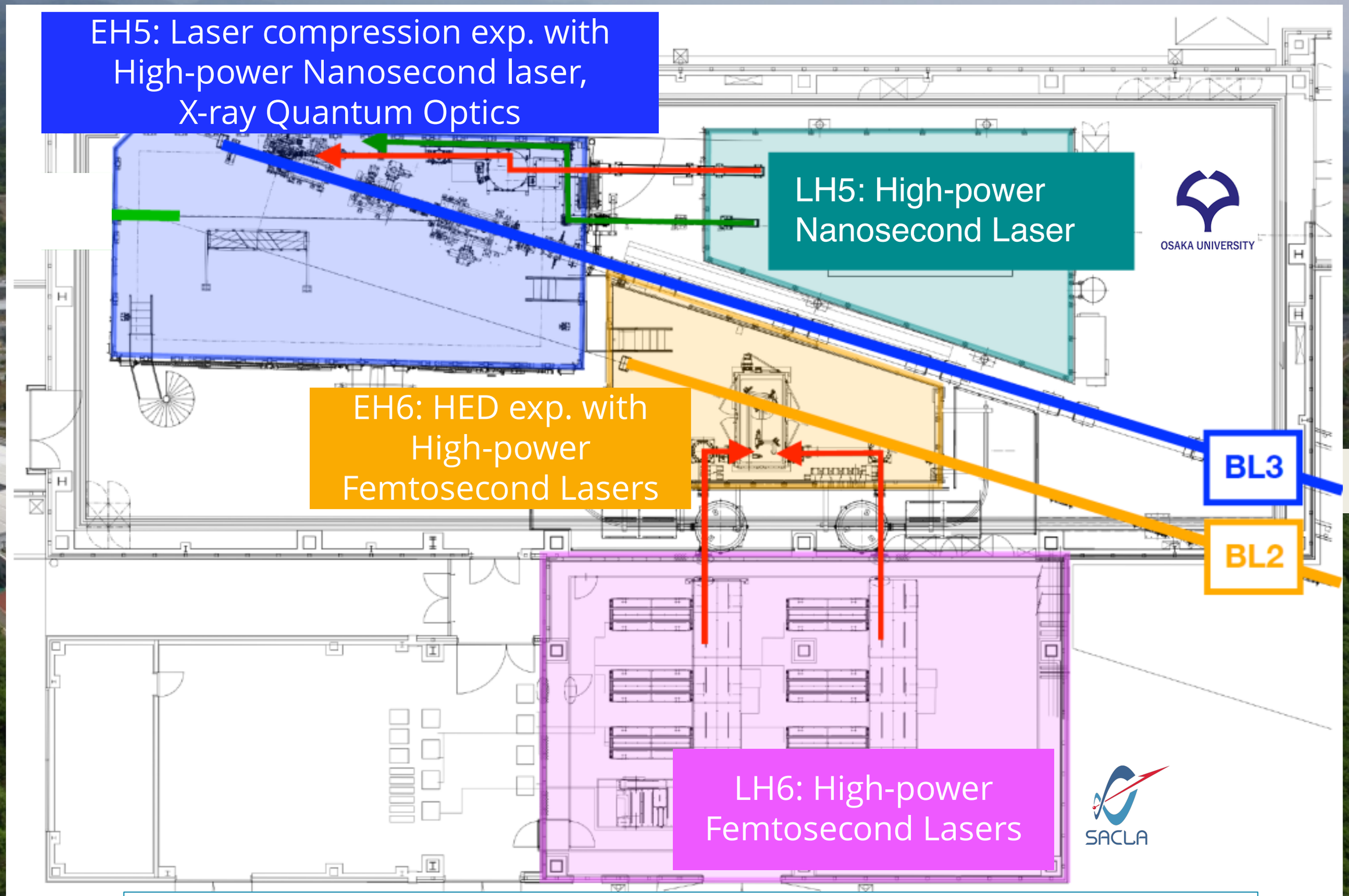
SACLA

Thales
Menlo Systems
Laser Quantum

SACLA

Experimental Platforms with High-Power Lasers at SACLA

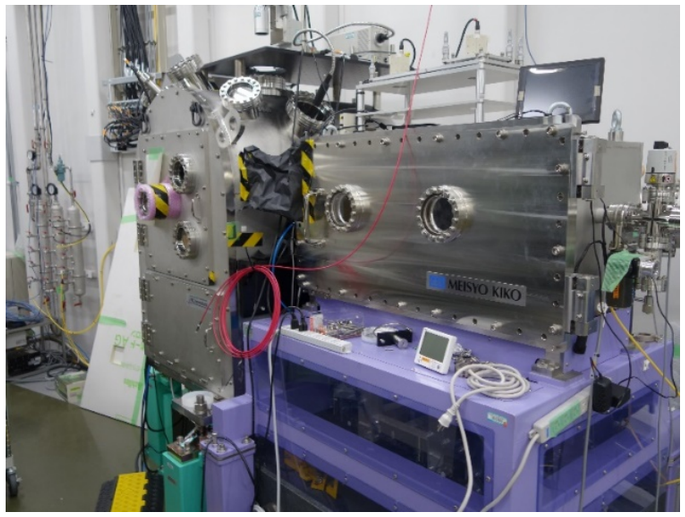
Experimental Platforms with High-Power Lasers at SACLA



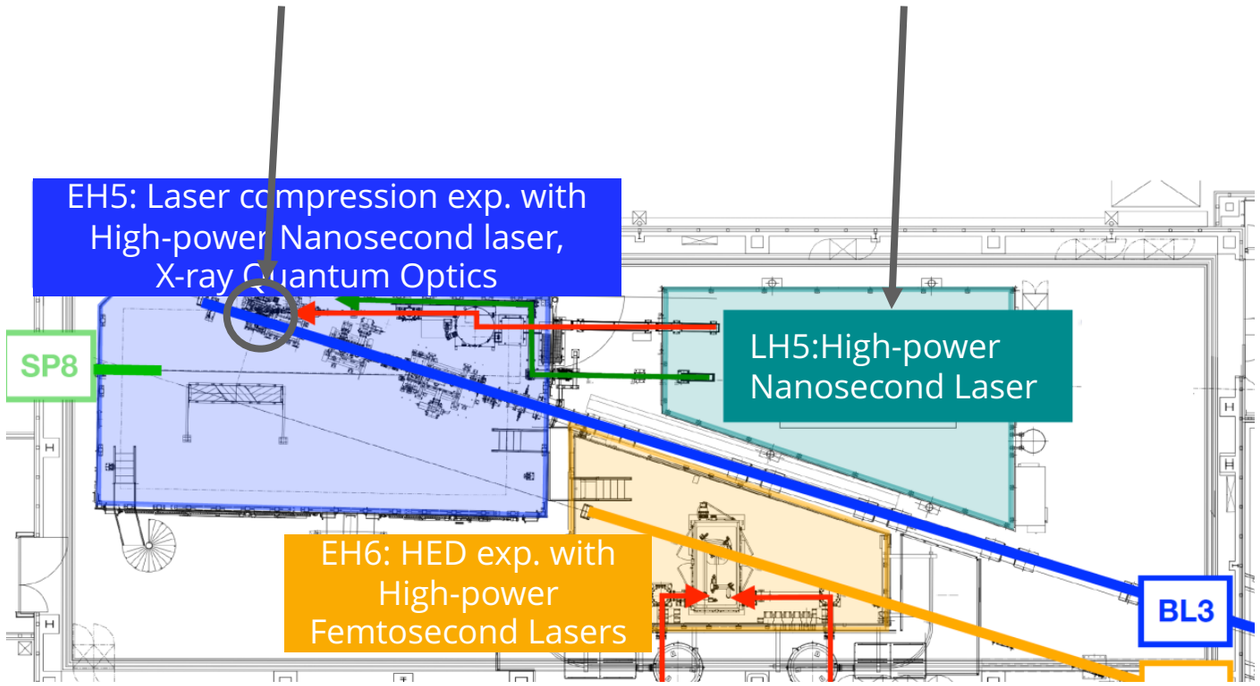
Virtual tour: at the end of this session 11:30 JST

Experimental platform with a high-power nanosecond laser

Experimental Chamber



Laser Bay



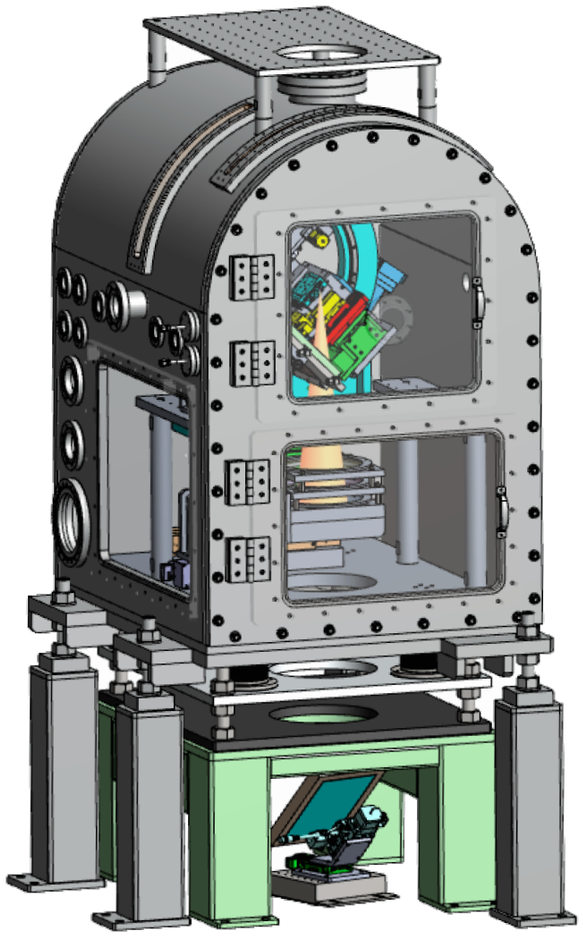
SACLA - SPring-8 Experimental Facility

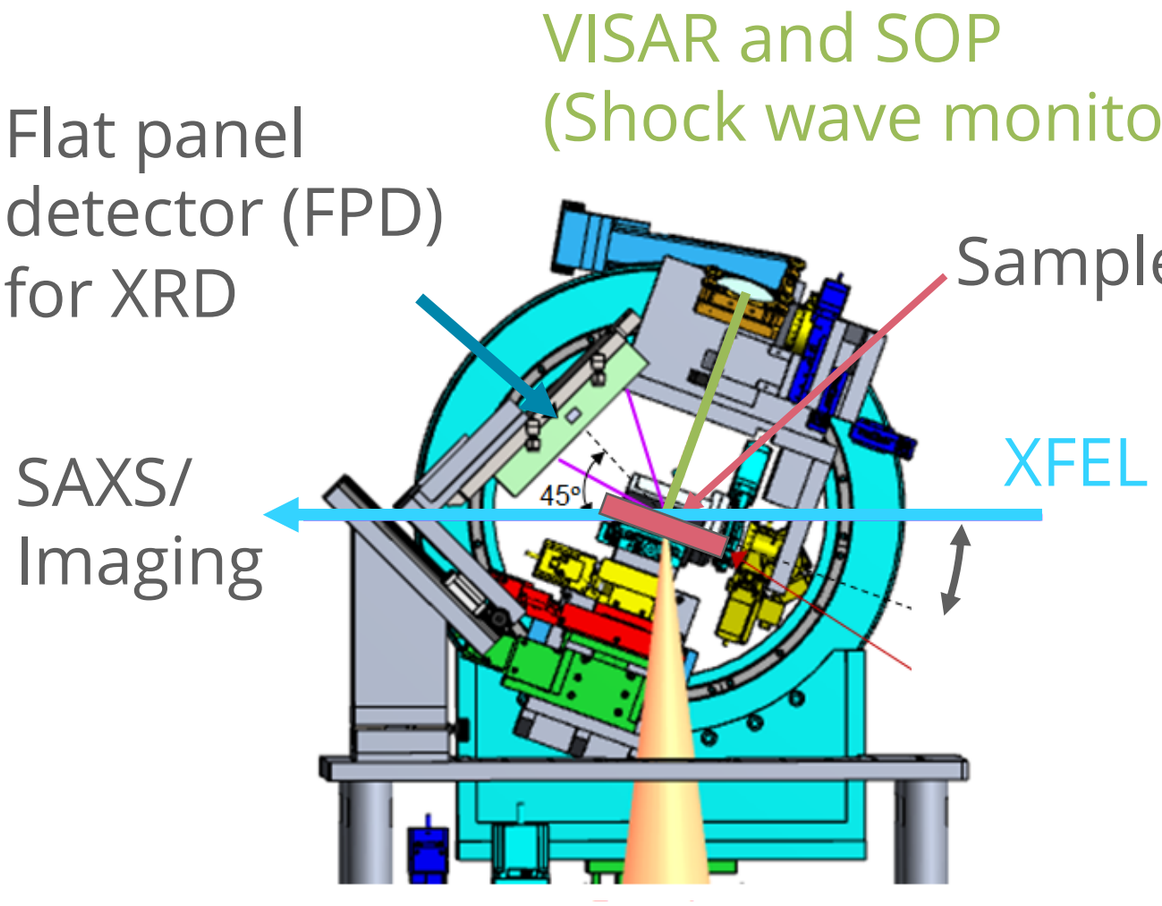
High-power nanosecond laser	
Pulse energy and duration	15J@5ns on sample(current)
Wavelength	532 nm
Rep. rate	0.1Hz

XFEL (BL3)	
Photon energy	4-20 keV
Band width	1.3 x 10^{-4}, ~5 x 10^{-3} (monochrome, pink beam)
Pulse energy	~600μJ @10keV
Pulse duration	<10 fs
Rep. rate	30 Hz
Focusing optics	KB mirror for focusing (down to 0.5 μm, 1D or 2D)
Advanced operation	Self-seeding Two color Split-and-delay optics

Experimental chamber is designed specifically for X-ray diffraction (XRD) and X-ray imaging/small-angle X-ray scattering (SAXS) experiments of laser-compressed materials using high-power nanosecond laser

Experimental chamber



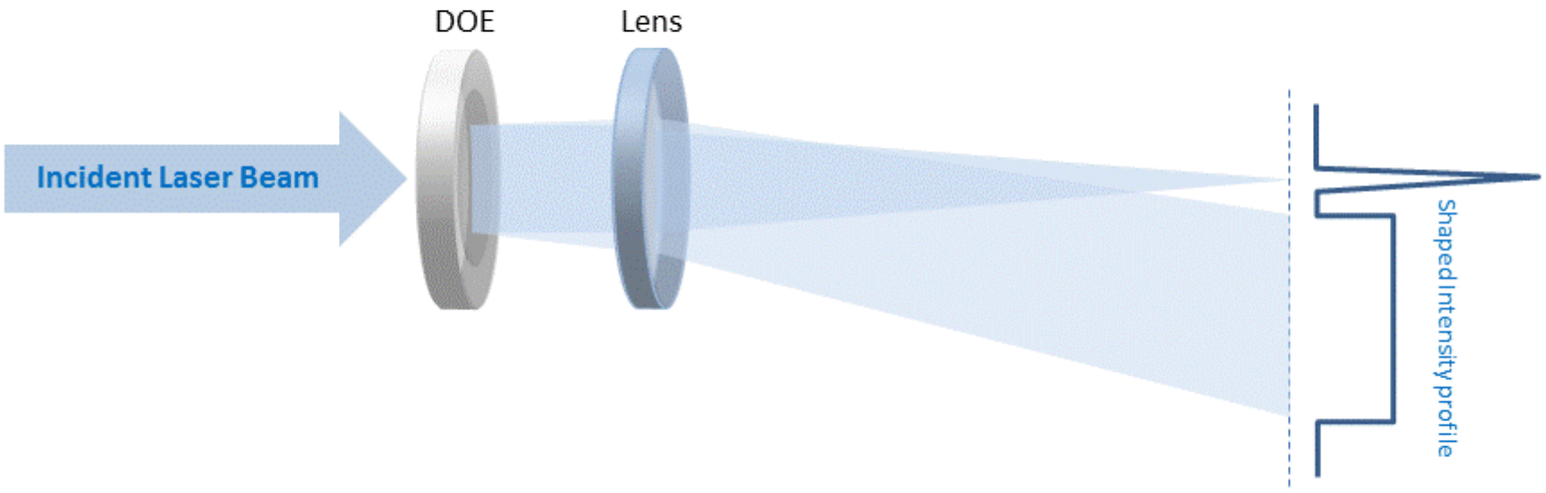


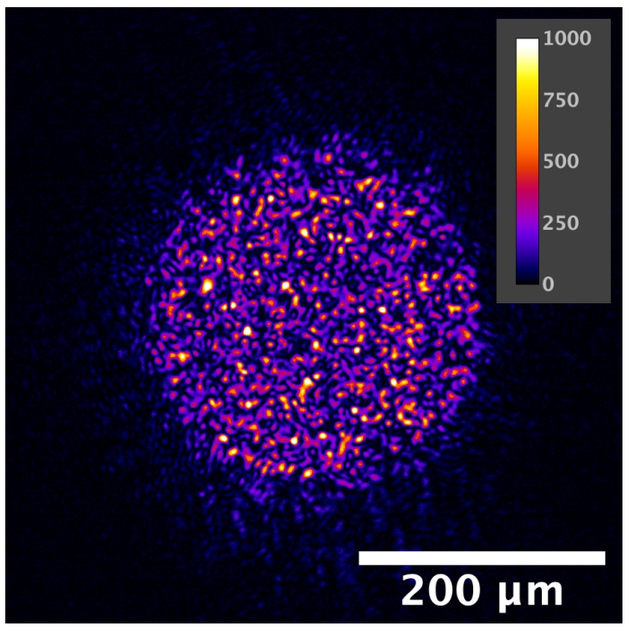
X-ray diffraction: Short talk G. Morard

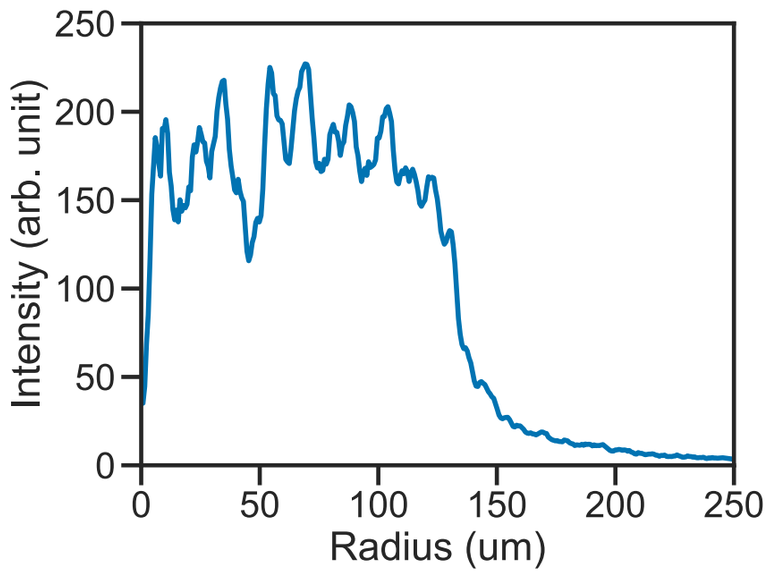
X-ray imaging: Short talk B. Albertazzi

Question
What additional diagnostics?

Diffractive optical elements (DOEs), or phase plates, for focal spot smoothing are now open to users





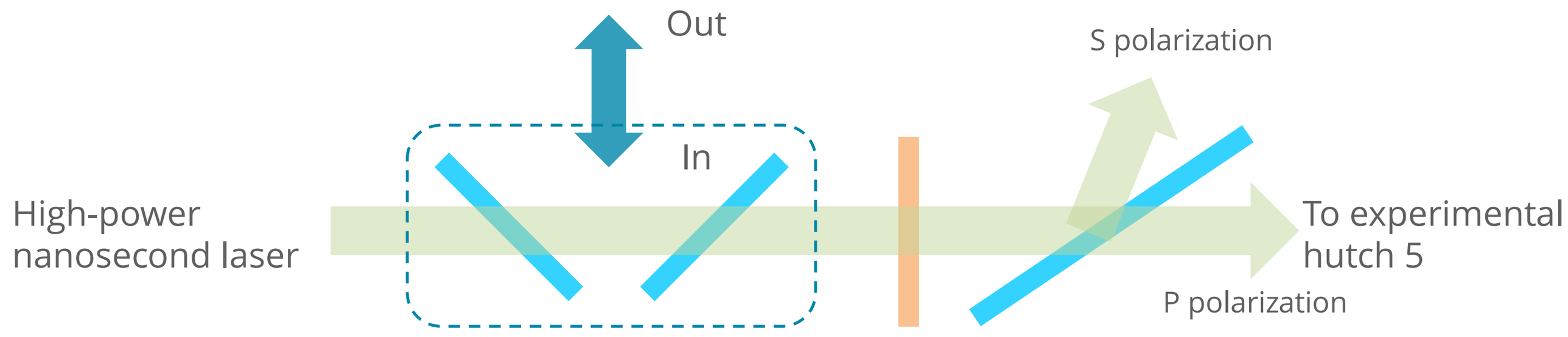


- Flat top profiles with diameters of 150 and 250 µm are now available
- Installations of DOEs for other spot sizes are planned
- Peripheral light from DOEs can damage neighboring samples
  - Shielding mask and another type of DOEs will be tested.

Question
What spot sizes?

Developed under the SACLA basic development program
by N. Ozaki/Osaka Univ., T. Okuchi/Kyoto Univ., and M. Koenig/LULI-CNRS.
(Talk N. Ozaki 11th March)

Variable and fixed attenuators for laser energy adjustment have been in operation since late 2020



Mirror pair λ/2 waveplate Polarizer

Fixed attenuator

- Mirror pair attenuates laser energy for laser characterization, synchronization, and pointing with fully amplified pulses
- Optical density > 6

Variable attenuator

- Polarizer coupled with waveplate provides continuously-variable attenuation of laser energy for intensity scan
- Optical density < 1

Further improvements are ongoing and planned

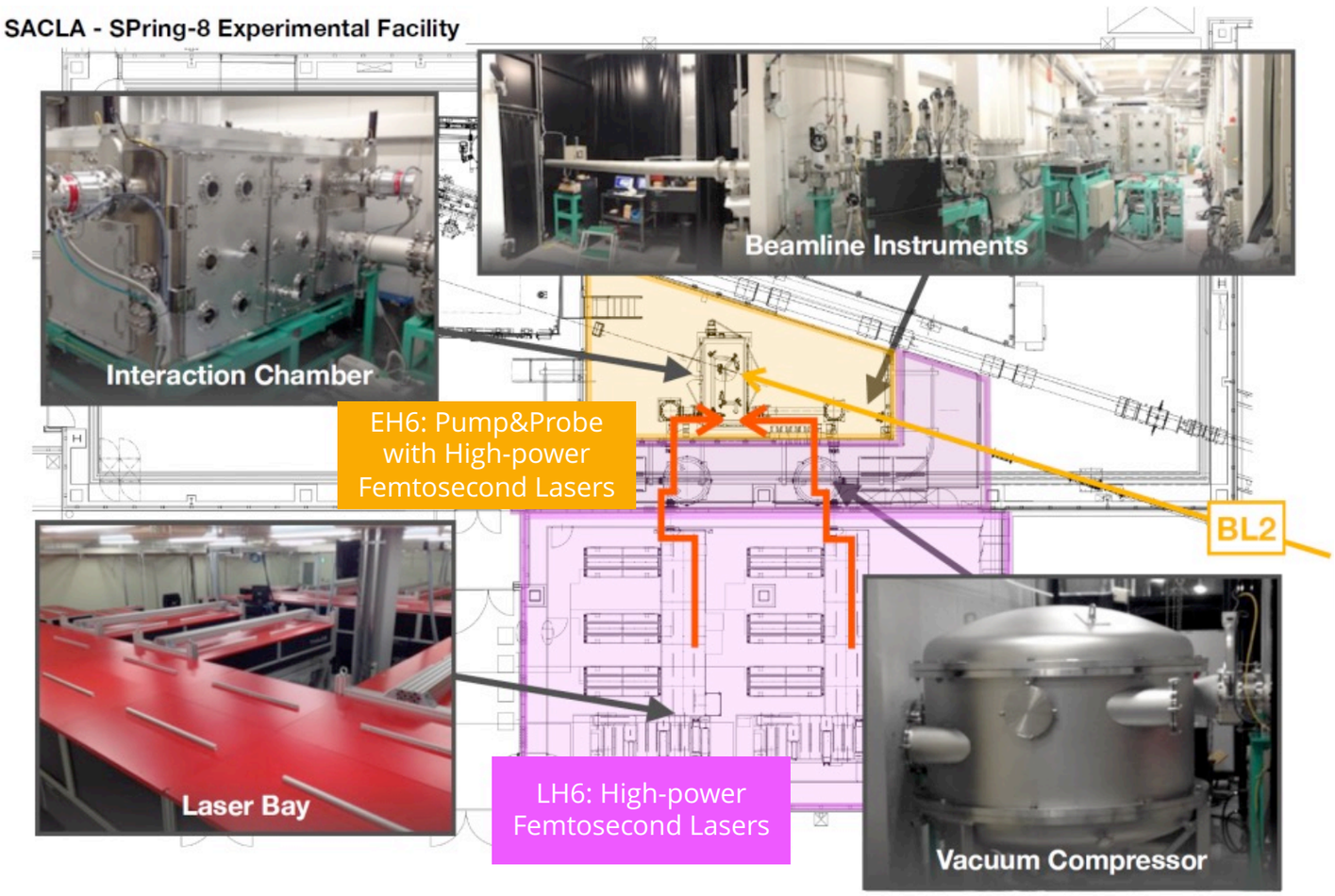
Development of user-friendly operation system

- Operation system integration of the high-power laser and diagnostics for users' experiments
- Automated data acquisition system and efficient data sharing system for non-standard detectors of SACLA (flat panel detector, streak cameras, laser monitors)

Developments of X-ray diagnostics for the platform

- The development of X-ray imaging system using a camera inside the chamber is under design consideration
- Other candidates: X-ray absorption spectroscopy, X-ray scattering spectroscopy
- Any inputs/requests are welcome

Experimental platform with high-power femtosecond lasers



High-power femtosecond laser	
Pulse energy	~8 J
Pulse duration	~40 fs (typ.)
Wavelength	800 nm
Rep. rate	1Hz
Timing jitter	~30 fs@RMS / 3 min.
Timing drift	+/- 500 fs / day

XFEL (BL2)	
Photon energy	4–15 keV
Band width	1.3×10^{-4}, $\sim 5 \times 10^{-3}$ (monochrome, pink beam)
Pulse energy	~500 μJ@10 keV
Pulse duration	<10 fs
Rep. rate	30 Hz
Focusing optics	CRLs for focus (~a few μm) Mirror for 1D focus (~a few um in vertical)

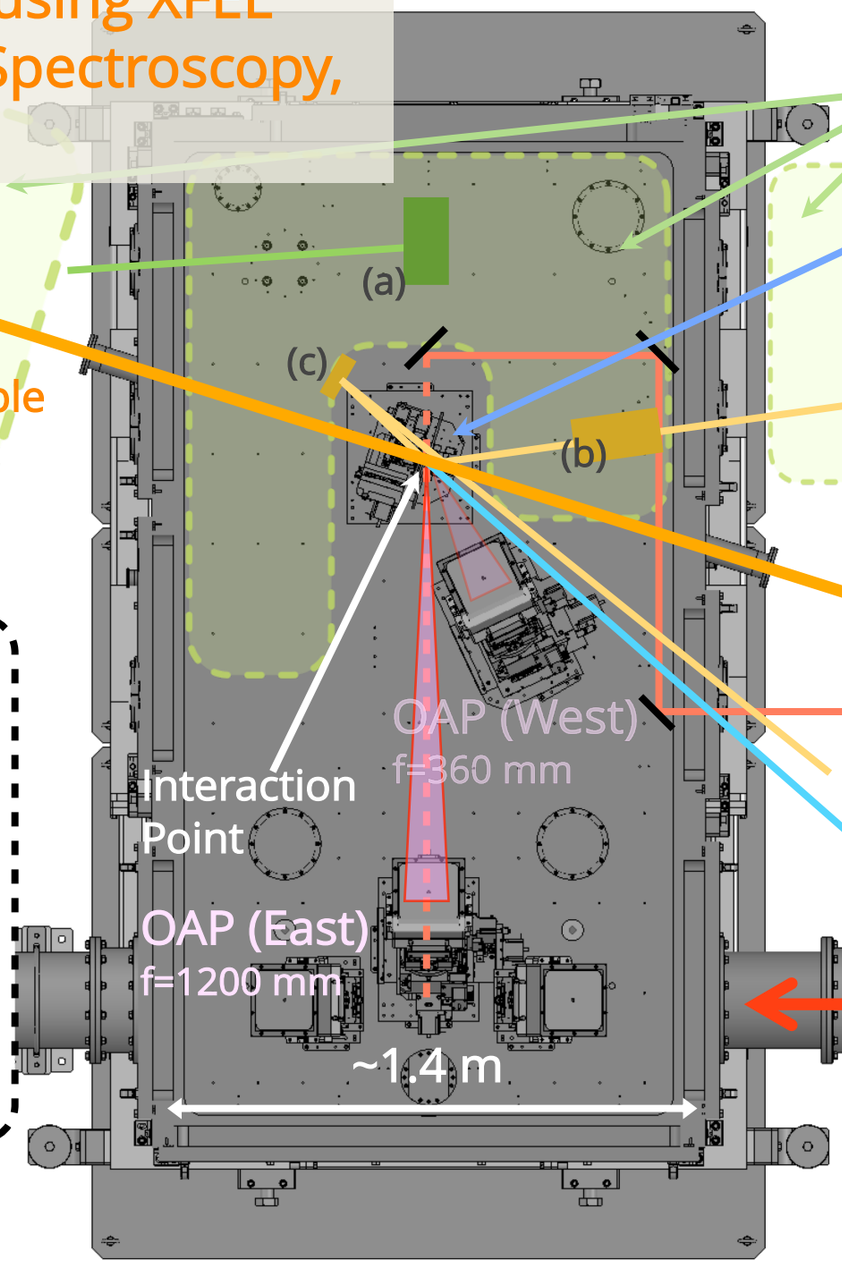
Basic instruments have been installed to regularly monitor laser-matter interactions for users' experiments

SAXS
Short talk: Y. Sakawa

Grazing-incidence X-ray scattering
Randolph+, arXiv:2012.15076 (2020)

Measurements using XFEL
SAXS, Imaging, Spectroscopy, etc.

up to ~4 m from sample



Available Space for Additional Diagnostics/Instruments

2D Scan Stages for Foils
Sample

XFEL (BL2)
Focus: CRLs for 2D, Mirror for 1D

Focus Monitor (opt. laser)
also used to adjust overlaps of opt. laser and XFEL in time and space

Sample Monitor

General Instruments

Optical Laser (East)

Single-Shot Diagnostics for Laser-Matter Interactions

(a) Electron Spec.
up to ~20 or ~45 MeV
Phosphor + Vis. CCD

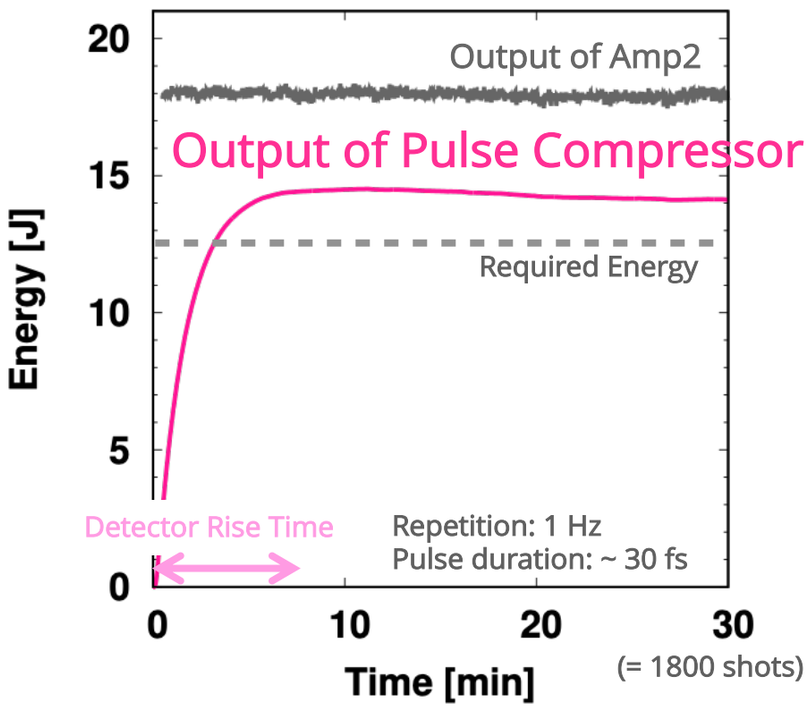
(b) X-ray Spec.
for Kα - Lyα of Ti - Ge
HAPG/HOPG/PET Crystal + MPCCD

(c) X-ray Imager
for Cu Kα with ~7x Magnification
Spherical Quartz 211 + X-ray CCD

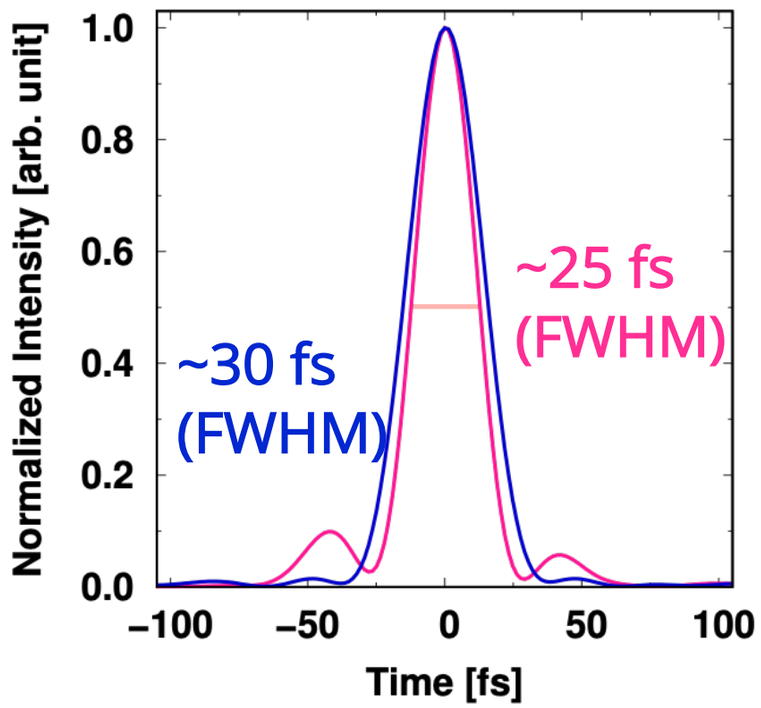
Measurements using XFEL are currently limited to around the optical axis of the XFEL due to the port arrangement of the chamber.
If you plan to measure away from the XFEL axis, please consult with us well in advance.

Pulse energy and duration have met requirements for 500 TW with >10^{10} contrast

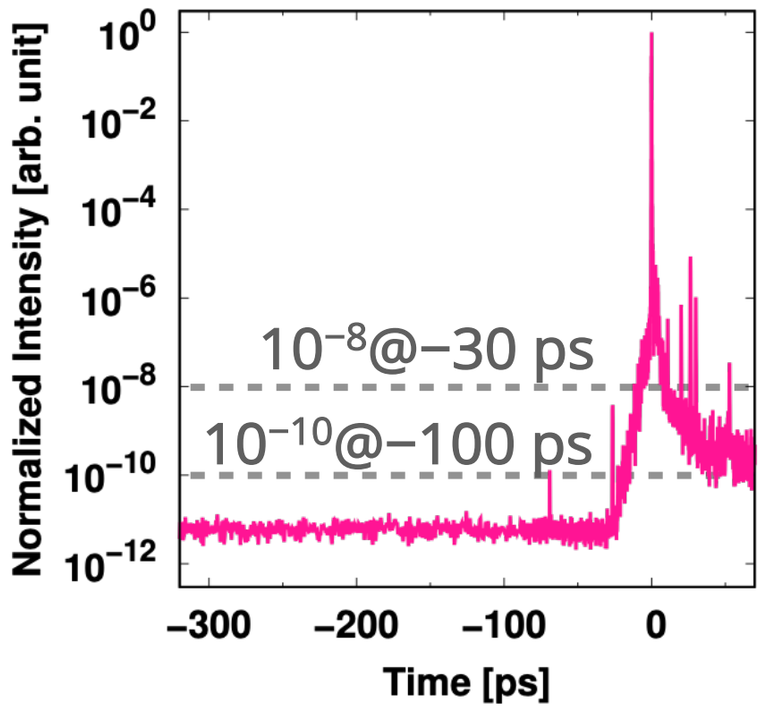
Pulse Energy ~14 J



Pulse Duration ~25 fs



Pulse Contrast >10^{10}

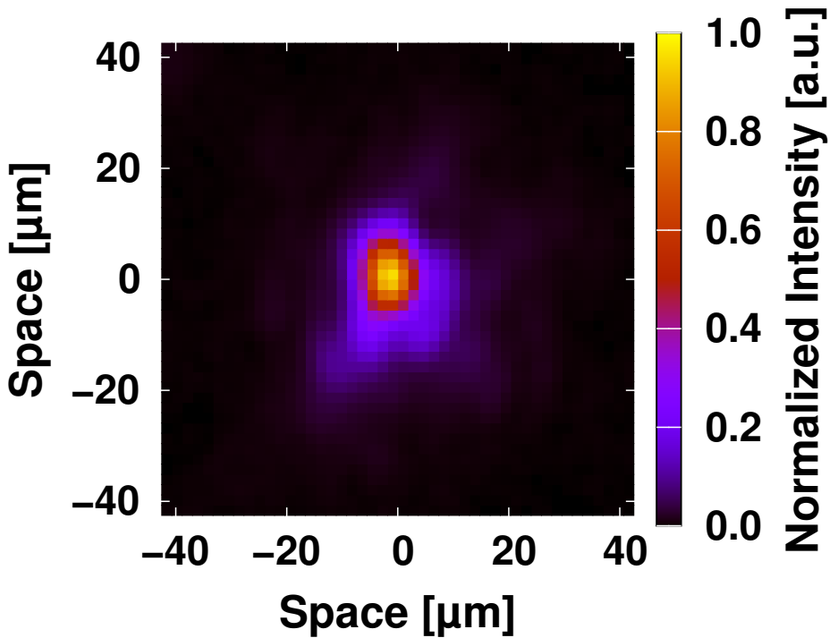


For users' experiments, pulse energy and duration are currently limited to up to 8 J after compressor and ~40 fs (~200 TW) for stable operation

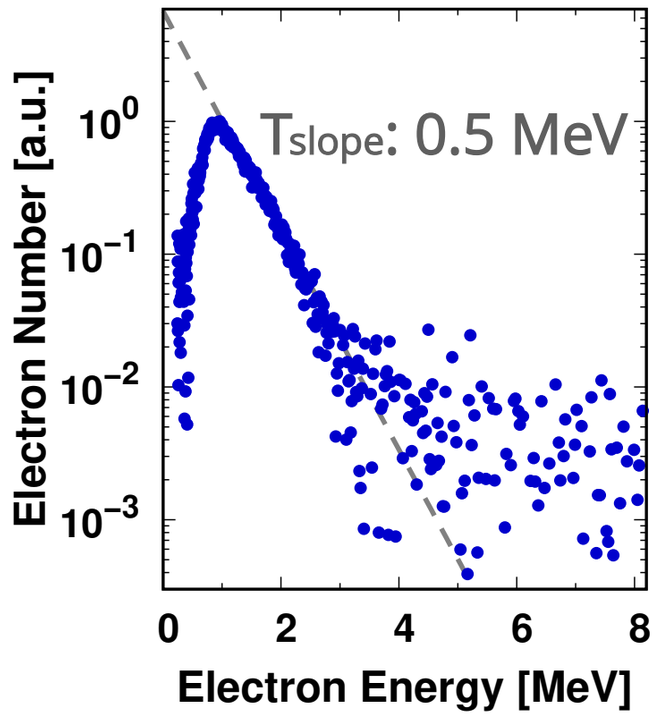
High-energy target shots have been carried out at focused intensities of ~10^{19} W/cm^2

2021 Feb. Data

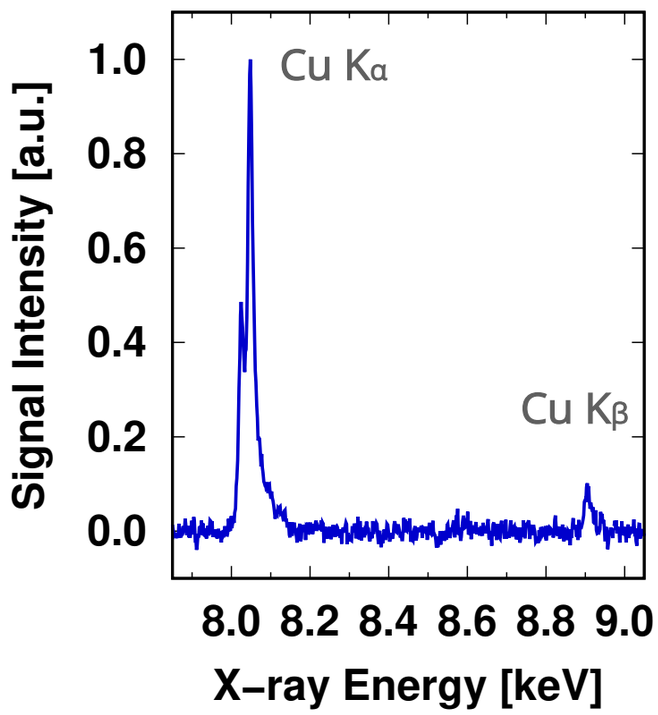
Focused Spot



Vacuum Electrons



Laser Produced X-rays

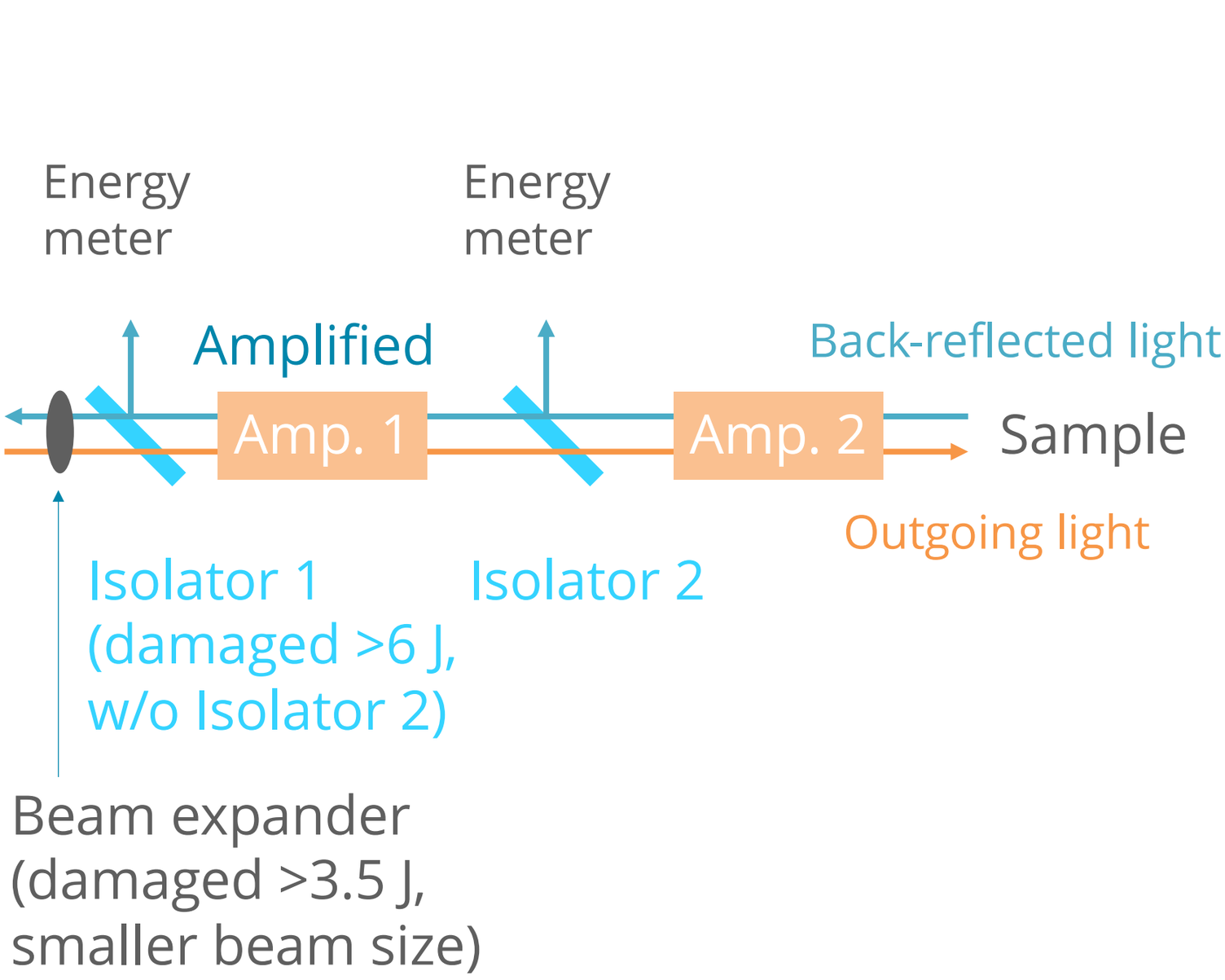


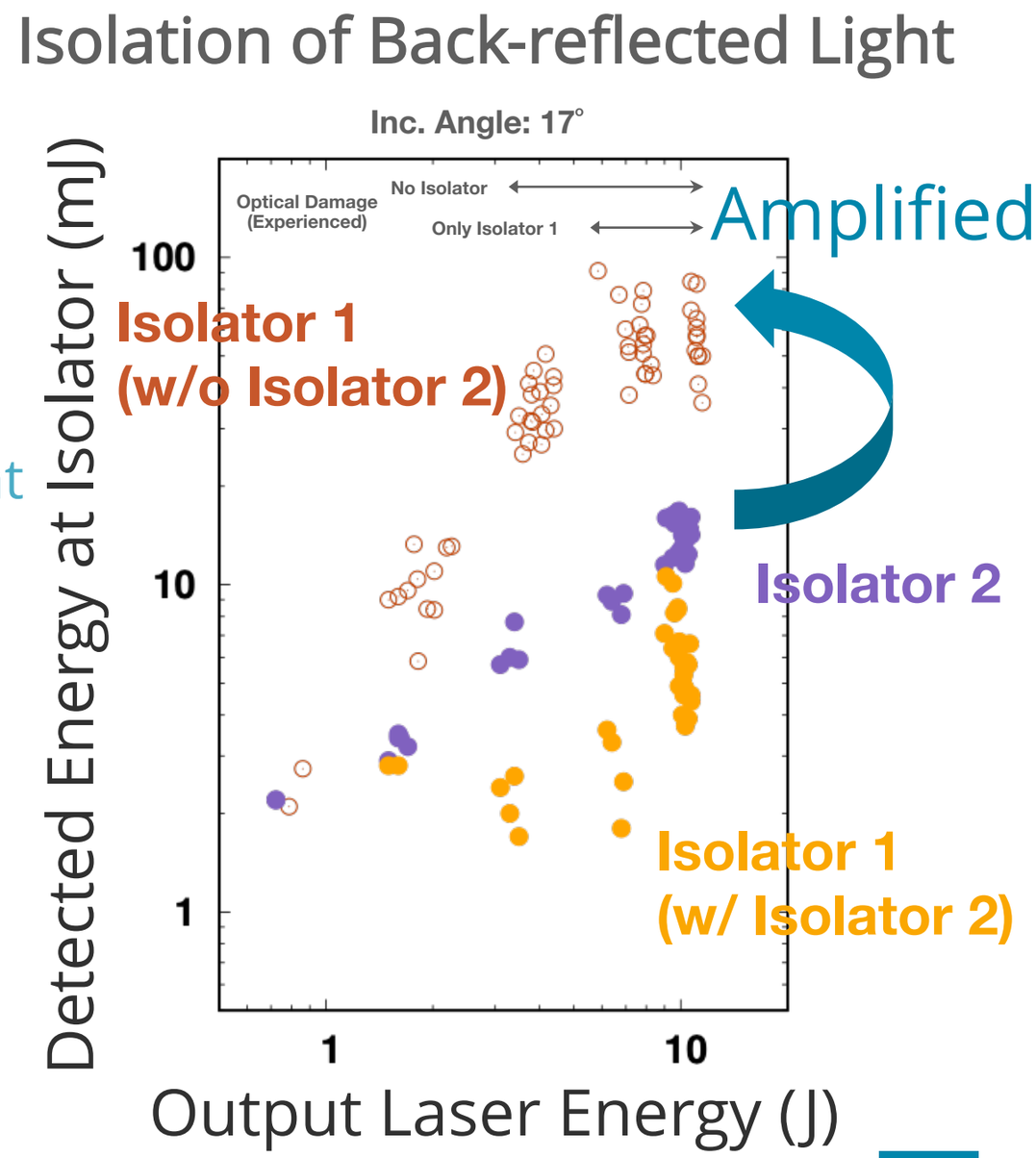
Focused profile is measured using attenuators (low reflective optics).

Laser energy: ~7 J on sample
Pulse duration: 30 fs
Inc. angle: 45 deg.

Installations of isolators for back reflected-light from samples have improved laser operation reliability at high energies

- Back-reflected light caused damage on optics, which limited the operational energy in 2019.
- Isolators of reflected light have been installed in 2020 that allow taking shots with high energies (~10 J).





Further development is planned to improve platform capabilities and stabilities

Improve Stability and Capability of High-power Optical Laser System

- Fixing the malfunction of some electrical components in the laser system, which has caused misfires is ongoing.
- Further stabilization of the synchro-lock system is underway.
- A monitoring system of the timing drift between the RF signal and the laser pulses is under examination.

Sample Exchange System under Vacuum Environment

- Automated sample exchange system is under development to minimize the vacuum break during beamtime.
- This system is beneficial not only to maximize the number of data shots but also to maintain the experimental conditions constant, for example, the optical laser focusing and timing.

Notes to proposal application to the platforms

Nanosecond laser

Osaka University had deployed the high-power nanosecond laser.

Any proposal using the experimental system is also regarded as a proposal for Collaborative Research of Institute of Laser Engineering (ILE), Osaka University.

Femtosecond laser

Due to resource constraints, the number of accepted proposals is limited to two or three per term (a half year).

Summary; experimental platforms with high-power lasers are available for users' experiments at SACLA

Nanosecond laser platform

- The experimental chamber is designed for X-ray diffraction, X-ray imaging, and small-angle X-ray scattering experiments of laser-compressed materials
- Current laser operation is 15 J on sample in 5 ns
- Diffractive optical elements (DOEs), or phase plates, for focal spot smoothing are now open to users
- Variable and fixed attenuators for laser energy adjustment have been in operation since late 2020

Femtosecond laser platform

- Basic instruments have been installed to regularly monitor laser-matter interactions for users' experiments
- Current laser operation is limited to 200 TW (8J, 40 fs) for stable operation
- Laser operation reliability at high energies has been improved by installations of isolators for back-reflected light

- Further development is planned to improve platforms capabilities and stabilities