SACLA Users' Meeting 2021, March 9-11, 2021

Experimental Platform with High-power Femtosecond Laser at SACLA

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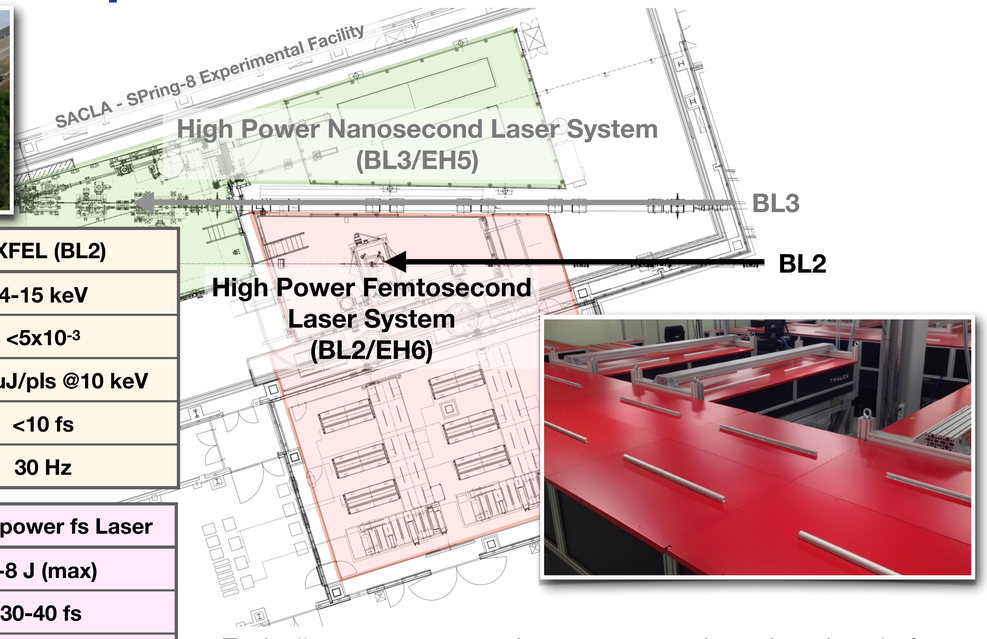
Summary

- **An experimental platform equipped with a high-power femtosecond laser system is available for user experiments mainly related to high energy density science (HEDS).**
- **Operation reliability of the laser system at high energies (~10 J) has been improved because of the newly-installed isolators that protect optics from the back-reflected light.**
- **Further development is planned to improve the research capabilities and the system stabilities of the platform.**

Experimental platform with high-power femtosecond laser has been opened for users since 2018A



Typical Parameters of XFEL (BL2)	
Photon Energy	4-15 keV
Band Width	<5x10^{-3}
Pulse Energy	~500 μJ/pls @10 keV
Pulse Duration	<10 fs
Repetition Rate	30 Hz

Typical Parameters of High-power fs Laser	
Laser Energy	7-8 J (max)
Pulse Duration	30-40 fs
Peak Power	~200 TW (max)
Number of Beams	1
Shot Rate	1 shot/~3 min

- Typically, two user experiments are conducted at the platform in every term (i.e. half a year).
- Achievable shot number per day varies from a few 10's to ~100, which strongly depends on the sample alignment complexity.

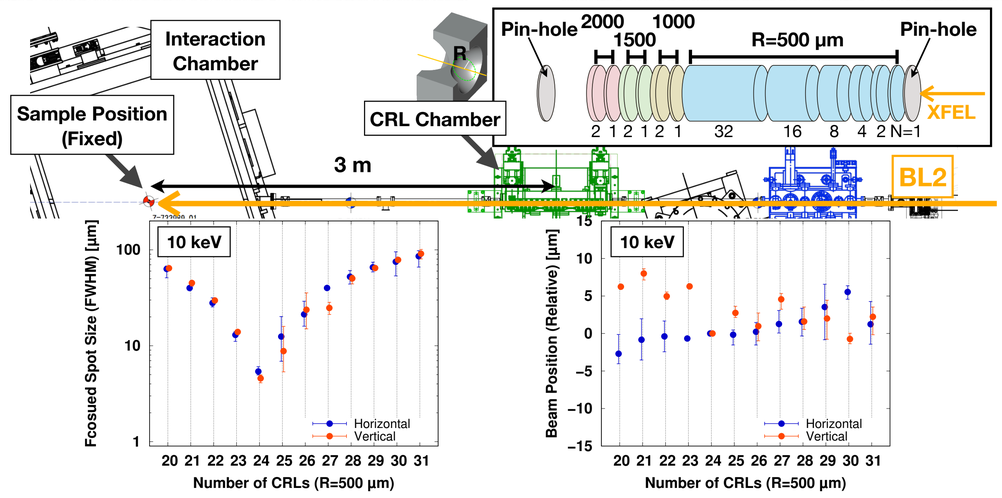
XFEL beam size at sample position can be adjusted from a few microns to ~1 mm (unfocused beam)

Example of XFEL Applications

- X-ray Imaging
- X-ray Scattering incl. SAXS
- X-ray Absorption Spectroscopy

CRL Focus Options

- Best Focus at Sample (a few μm)
- Focused before/after Sample
- Unfocused Beam (~1 mm dia.)

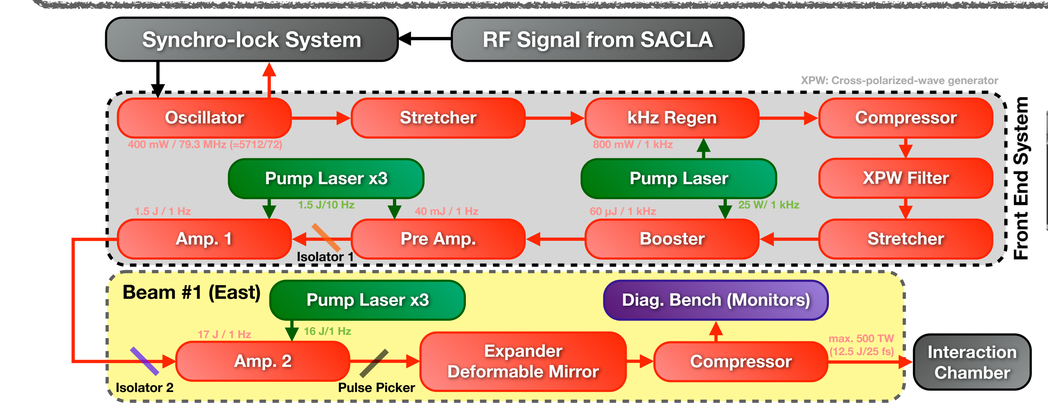


- In addition to the 2D focus by compound refractive lenses (CRLs), a 1D focus system using a mirror has been developed recently. The system focuses the beam down to a few microns only in the vertical direction.

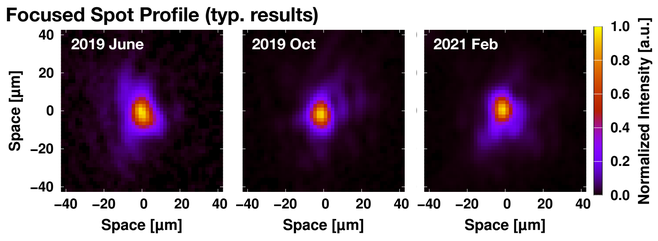
Laser operation reliability at high energies has been improved by installations of isolators for back-reflected light

Major Issues Appeared in FY2019

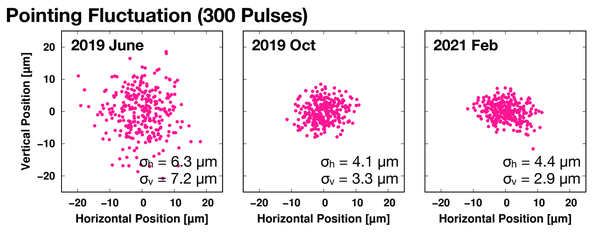
- **Damage on optical components in the laser system caused by reflected light from samples after improvements of the focused beam pattern**
- **Malfunction of electrical components of the laser system**



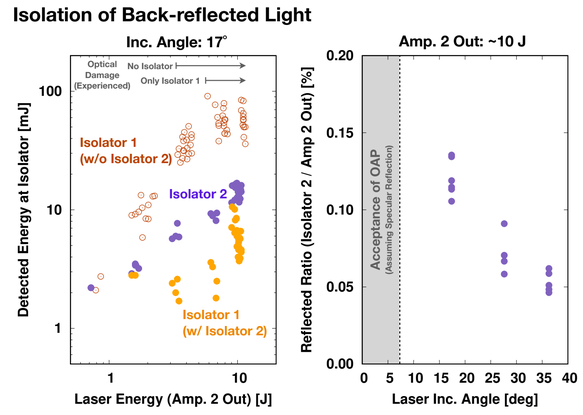
Focused Spot Profile (typ. results)



Pointing Fluctuation (300 Pulses)



Isolation of Back-reflected Light

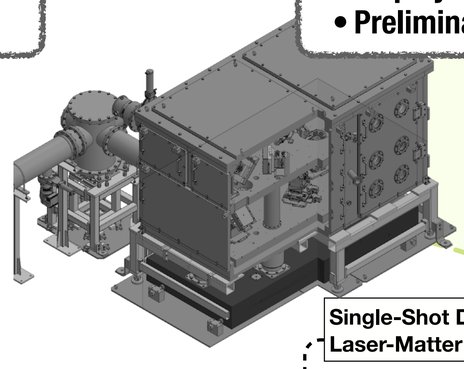


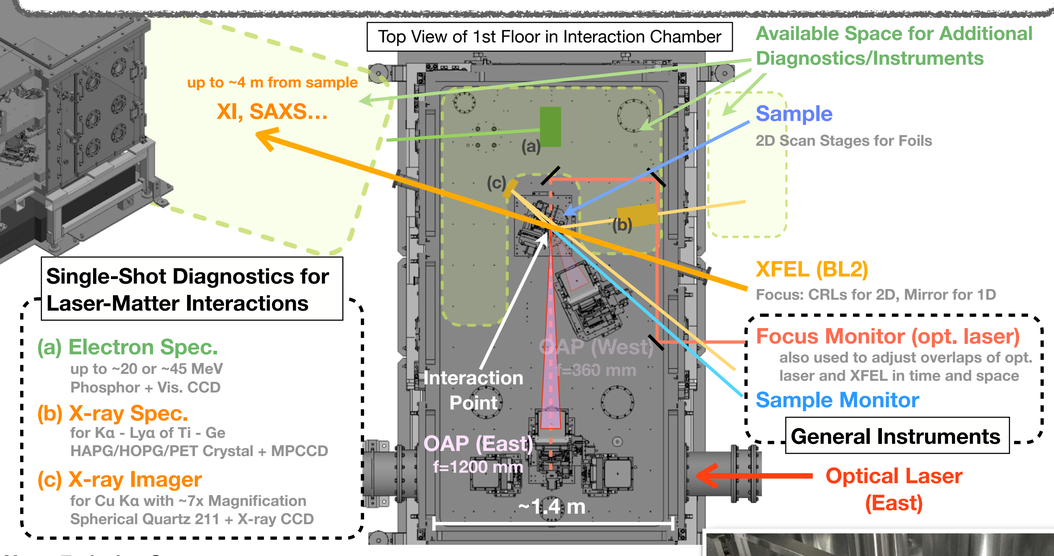
- Wavefront of amplified laser pulses can be effectively corrected with an attenuation system since 2019, resulting in improvements of focused beam profile on high power shots.
- Back-reflected light caused damage on optics, which limited the operational energy in 2019. Isolators of reflected light have been installed in 2020 that allow taking shots with high energies (~10 J).
- Pointing stabilities have been also improved mainly due to the beam stabilization at the XPW system.

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

Updates and Improvements in FY2020

- **Resolution improvements of the x-ray emission spectrometer by employing a thin HAPG crystal instead of a thick HOPG crystal**
- **Preliminary examination of energetic ion production**





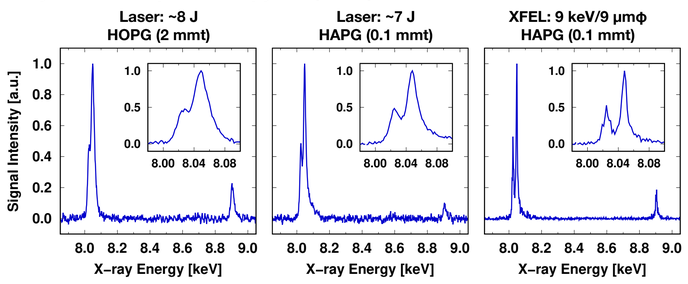
Single-Shot Diagnostics for Laser-Matter Interactions

(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

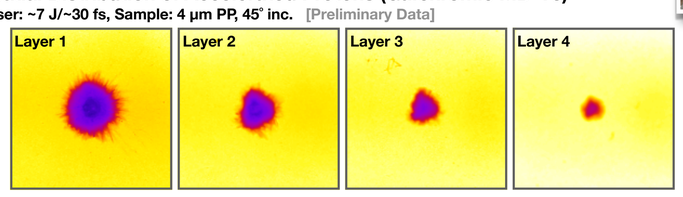
(c) X-ray Imager
for Cu Kα with ~7x Magnification
Spherical Quartz 211 + X-ray CCD

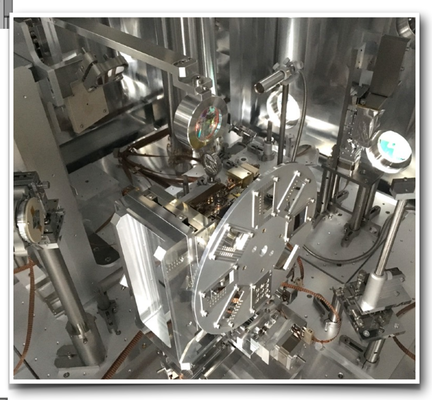
X-ray Emission Spectroscopy Sample: 20 μm Cu



Spatial Distribution of Accelerated Protons (Gafchromic MD-V3)

Laser: ~7 J/~30 fs, Sample: 4 μm PP, 45° inc. [Preliminary Data]





Further development is planned to improve platform capabilities and stabilities

Improve Stability and Capability of High-power Optical Laser System

- Malfunction of some electrical components in the laser system has caused misfires in past users' experiments. We have been working with the laser developer to fix the issue.
- Further stabilization of the synchro-lock system is underway.
- Monitoring of the laser arrival timing is a key to improve the pump-probe capability. A monitoring system of the timing drift between the RF signal and the laser pulses is under examination.

Remote Experiments

- Experiments using typical (i.e. standard) configuration at this platform require limited hands-on work, which has been mostly carried out by the beamline staff.
- The rest work, for example, aligning samples and taking shots, will be conducted by users remotely once the remote system is ready to use. Pilot experiments are expected to start in FY2021.

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.