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Experimental Platform with High-power Femtosecond Laser at SACLA

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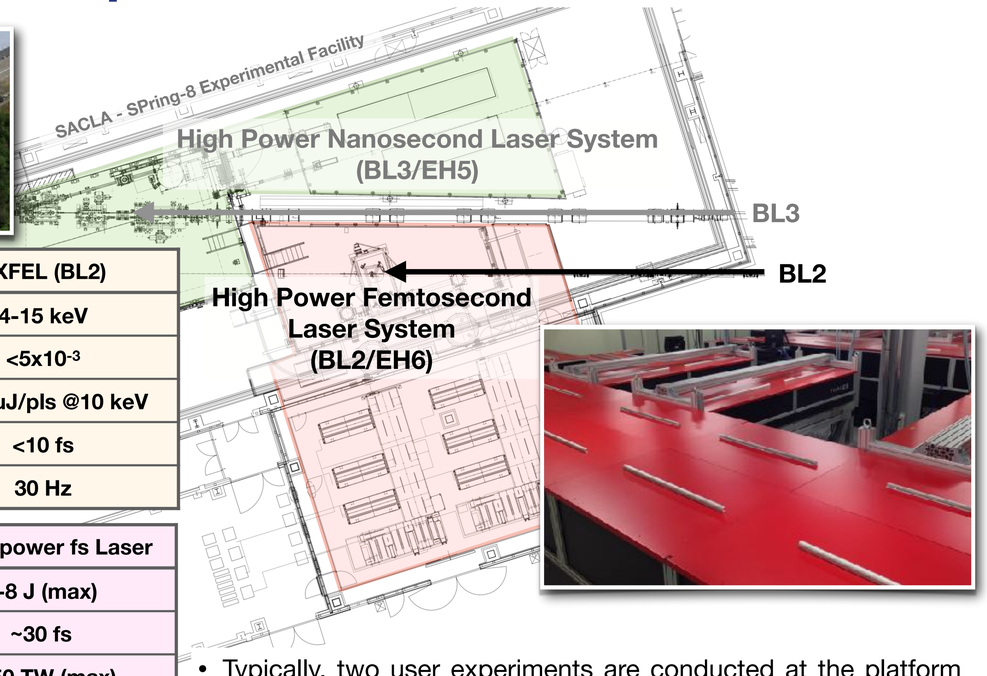
Summary

- **An experimental platform equipped with a high-power femtosecond laser system is available for user experiments mainly related to high energy density science (HEDS).**
- **First remote experiment has been carried out with external control capabilities of beamline equipment in February 2022 at this platform.**
- **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 fs
Peak Power	~250 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.

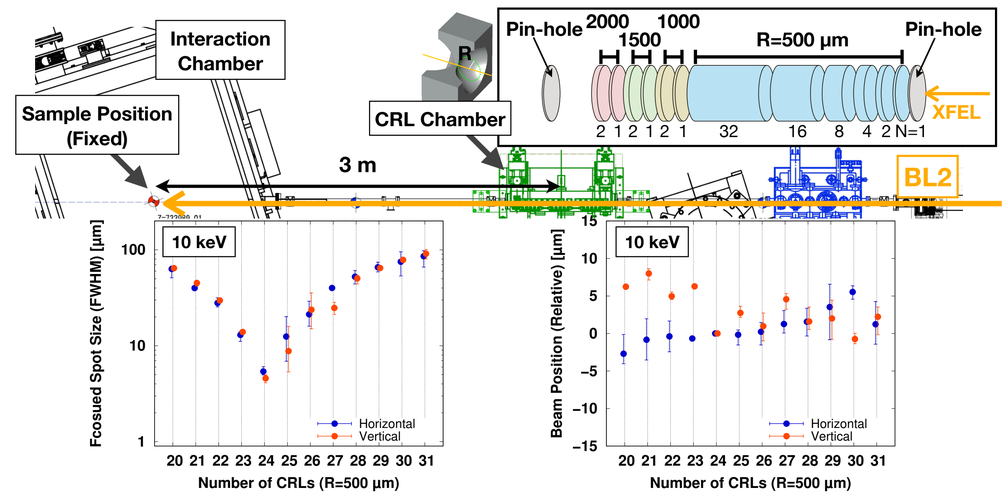
XFEL beam size at sample position can be adjusted from a few microns to ~1 mm (unfocused beam)

Example of XFEL Applications

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

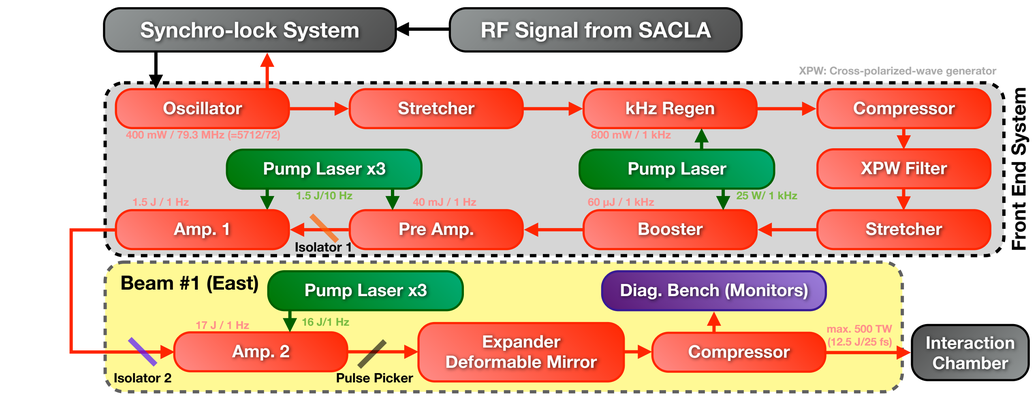
CRL Focus Options

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

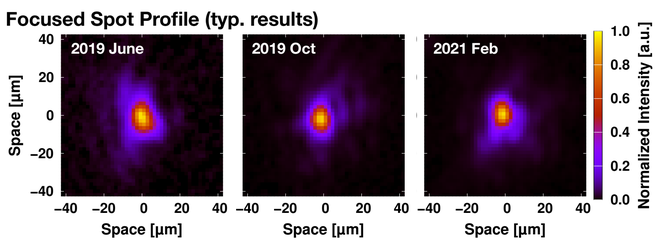


- In addition to the 2D focus by compound refractive lenses (CRLs), a 1D focus system using a mirror has been utilized. The system focuses the beam down to a few microns only in the vertical direction.

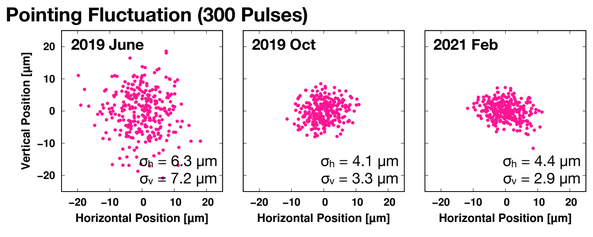
Laser operation reliability at high energies has been improved by installations of isolators for back-reflected light



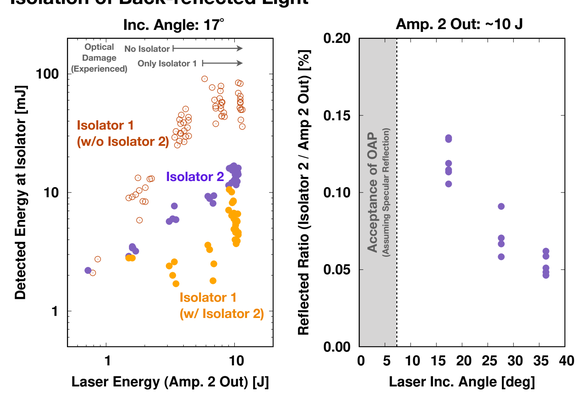
Focused Spot Profile (typ. results)



Pointing Fluctuation (300 Pulses)



Isolation of Back-reflected Light

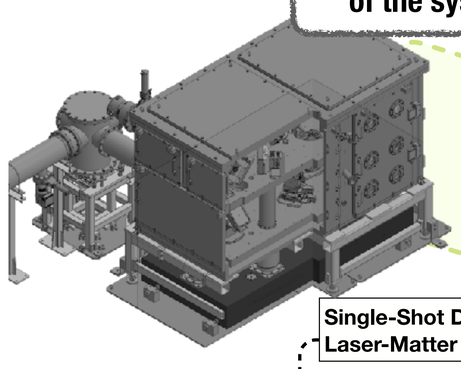


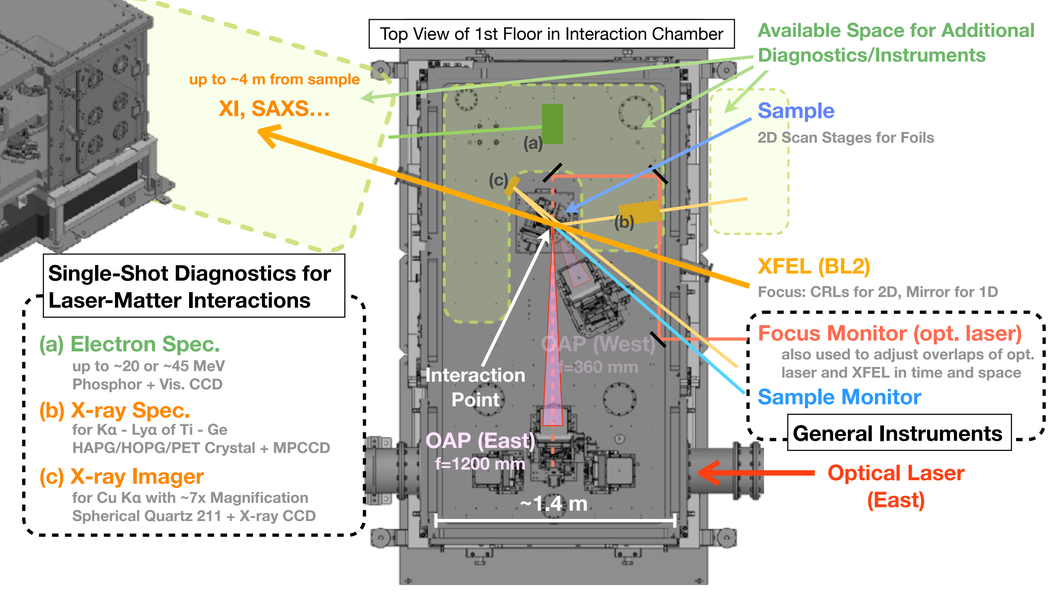
- Wavefront of amplified laser pulses can be effectively corrected with an attenuation system since 2019, resulting in improvements of focused beam profile on high power shots.
- Back-reflected light caused damage on optics, which limited the operational energy in 2019. Isolators of reflected light have been installed in 2020 that allow taking shots with high energies (~10 J) at incident angles above ~17°.
- 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 FY2021

- **Spatial resolution of the x-ray imager using a spherical quartz for Cu Ka x-rays has been optimized thanks to a motorized stages to adjust the focus of the system**

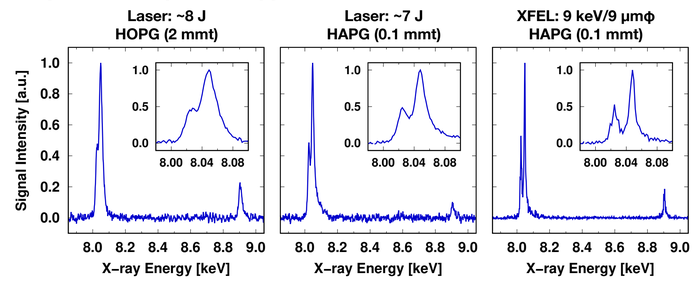




Single-Shot Diagnostics for Laser-Matter Interactions

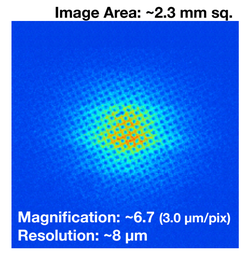
- **(a) Electron Spec.**
  up to ~20 or ~45 MeV
  Phosphor + Vis. CCD
- **(b) X-ray Spec.**
  for Kα - Lyα of Ti - Ge
  HAPG/HOPG/PET Crystal + MPCCD
- **(c) X-ray Imager**
  for Cu Kα with ~7x Magnification
  Spherical Quartz 211 + X-ray CCD

X-ray Emission Spectroscopy Sample: 20 μm Cu

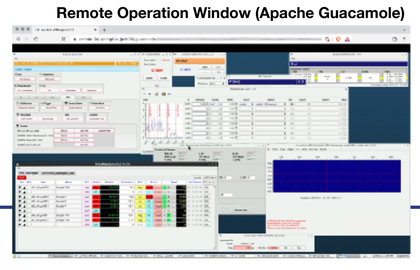


Cu Ka Imager

Sample: Cu TEM Grid (400 mesh)
Image Area: ~2.3 mm sq.



Remote Operation Window (Apache Guacamole)



Remote operation system has been utilized in user's experiment for the first time

- First remote experiment has been carried out successfully with external control capabilities of beamline equipment in February 2022 at this platform.
- Users operated the beamline equipment remotely for aligning samples and taking shots with the XFEL and the optical laser.

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 in collaboration of laser manufacturer.
- 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.

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.