Capability, updates, and development plans of the experimental platform with high-power nanosecond laser at SACLA

Kohei Miyanishi on behalf of SACLA
SACLA
SACLA Users' Meeting 2022, 2nd March 2022
Breakout session A2: "New perspectives using the coupling between high-power nanosecond laser and XFEL at SACLA"

SACLA

High-power laser systems are 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.

OSAKA UNIVERSITY

Prof. Ozaki, Prof. Kodama

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

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

High-power Femtosecond Laser

See poster "Experimental Platform with High-power Femtosecond Laser at SACLA"

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

SACLA XFEL

This session

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.

OSAKA UNIVERSITY

Prof. Ozaki, Prof. Kodama

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

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

High-power Femtosecond Laser

See poster “Experimental Platform with High-power Femtosecond Laser at SACLA”

Recent activities at the high-power nanosecond laser platform

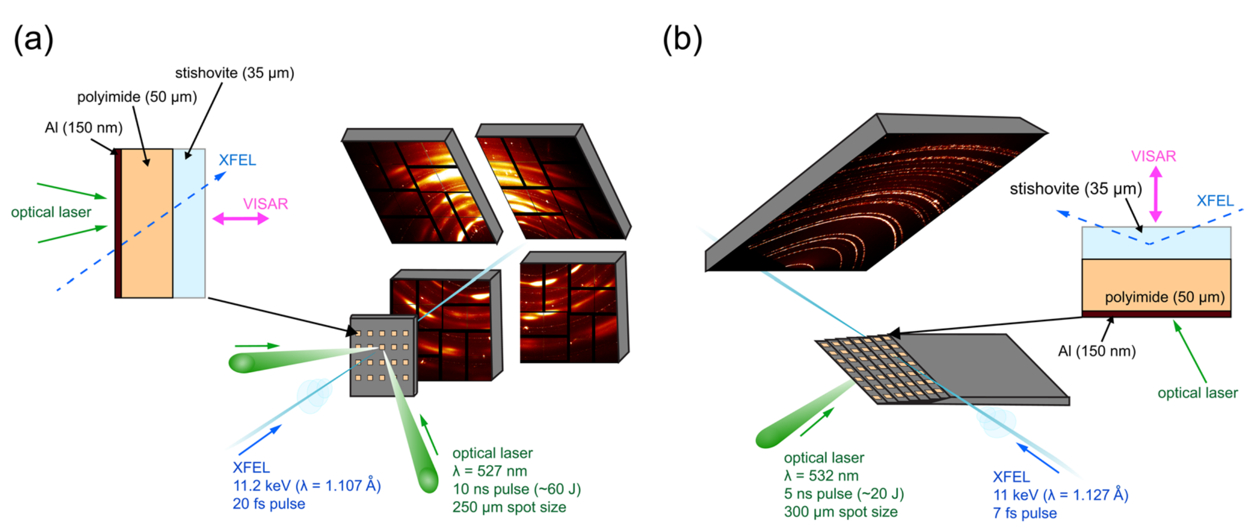
SCIENTIFIC REPORTS
natureresearch

Check for updates

OPEN

Evidence of shock-compressed stishovite above 300 GPa

Markus O. Schoelmerich[1] ✉, Thomas Tschentscher[1], Shrikant Bhat[2], Cindy A. Bolme[3], Eric Cunningham[4], Robert Farla[2], Eric Galtier[4], Arianna E. Gleason[4], Marion Harmand[5], Yuichi Inubushi[6,7], Kento Katagiri[8], Kohei Miyanishi[6], Bob Nagler[4], Norimasa Ozaki[8], Thomas R. Preston[1], Ronald Redmer[9], Ray F. Smith[10], Tsubasa Tobase[11], Tadashi Togashi[6,7], Sally J. Tracy[12], Yuhei Umeda[8], Lennart Wollenweber[1], Toshinori Yabuuchi[6,7], Ulf Zastrau[1] & Karen Appel[1]



M. O. Schoelmerich et. al., *Sci. Rep.* 10, 10197 (2020).

nature COMMUNICATIONS

ARTICLE

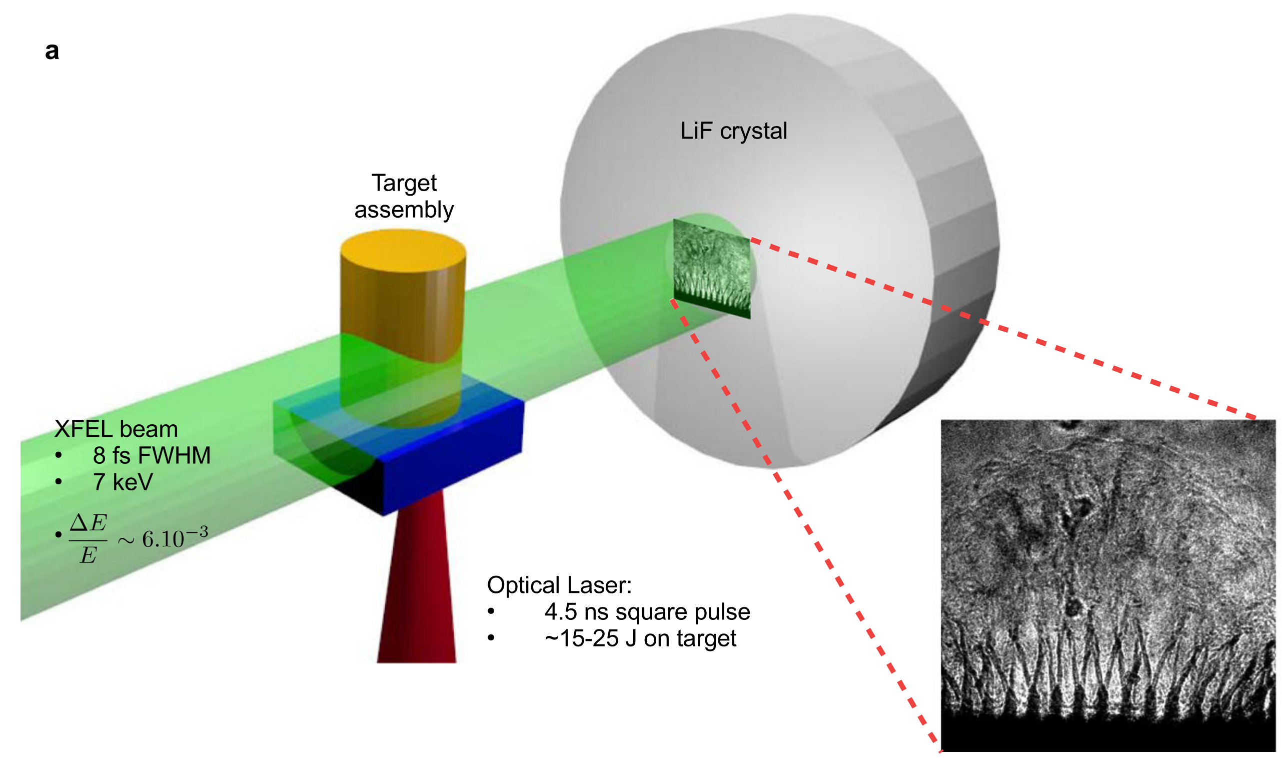
Check for updates

https://doi.org/10.1038/s41467-021-22891-w

OPEN

Micron-scale phenomena observed in a turbulent laser-produced plasma

G. Rigon[1] ✉, B. Albertazzi[1], T. Pikuz[2,3], P. Mabey[1], V. Bouffetier[4], N. Ozaki[5,6], T. Vinci[1], F. Barbato[4], E. Falize[7], Y. Inubushi[8,9], N. Kamimura[5], K. Katagiri[5], S. Makarov[3,10], M. J.-E. Manuel[11], K. Miyanishi[9], S. Pikuz[3,12], O. Poujade[7,13], K. Sueda[9], T. Togashi[8,9], Y. Umeda[5,14], M. Yabashi[8,9], T. Yabuuchi[8,9], G. Gregori[15], R. Kodama[5], A. Casner[4,16] & M. Koenig[1,5]



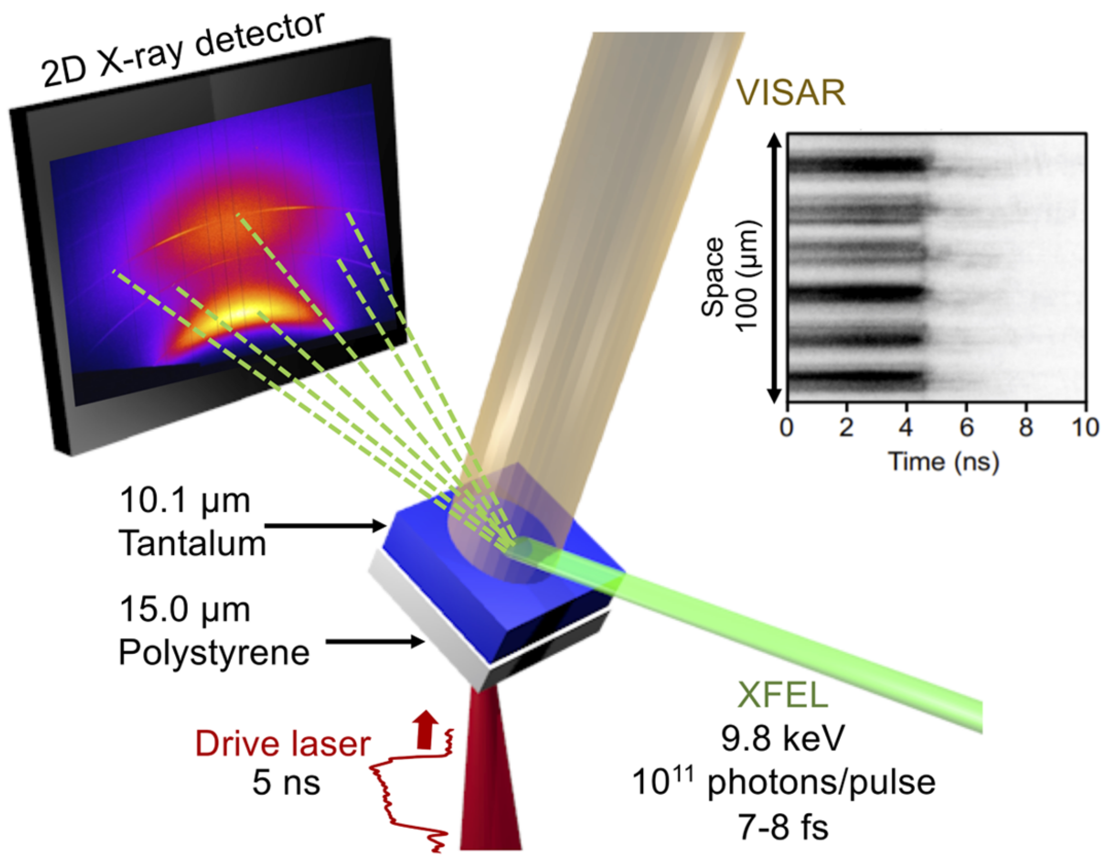
G. Rigon et. al., *Nat. Commun.* 12, 2679 (2021).

Recent activities at the high-power nanosecond laser platform

PHYSICAL REVIEW LETTERS **126,** 175503 (2021)

Liquid Structure of Tantalum under Internal Negative Pressure

K. Katagiri,[1,2,*] N. Ozaki,[1,2] S. Ohmura,[3] B. Albertazzi,[4] Y. Hironaka,[2,5] Y. Inubushi,[6,7] K. Ishida,[1] M. Koenig,[1,4] K. Miyanishi,[7] H. Nakamura,[1] M. Nishikino,[8] T. Okuchi,[9] T. Sato,[10] Y. Seto,[11] K. Shigemori,[2] K. Sueda,[7] Y. Tange,[6] T. Togashi,[6,7] Y. Umeda,[12] M. Yabashi,[6,7] T. Yabuuchi,[6,7] and R. Kodama[1,2]



nature COMMUNICATIONS

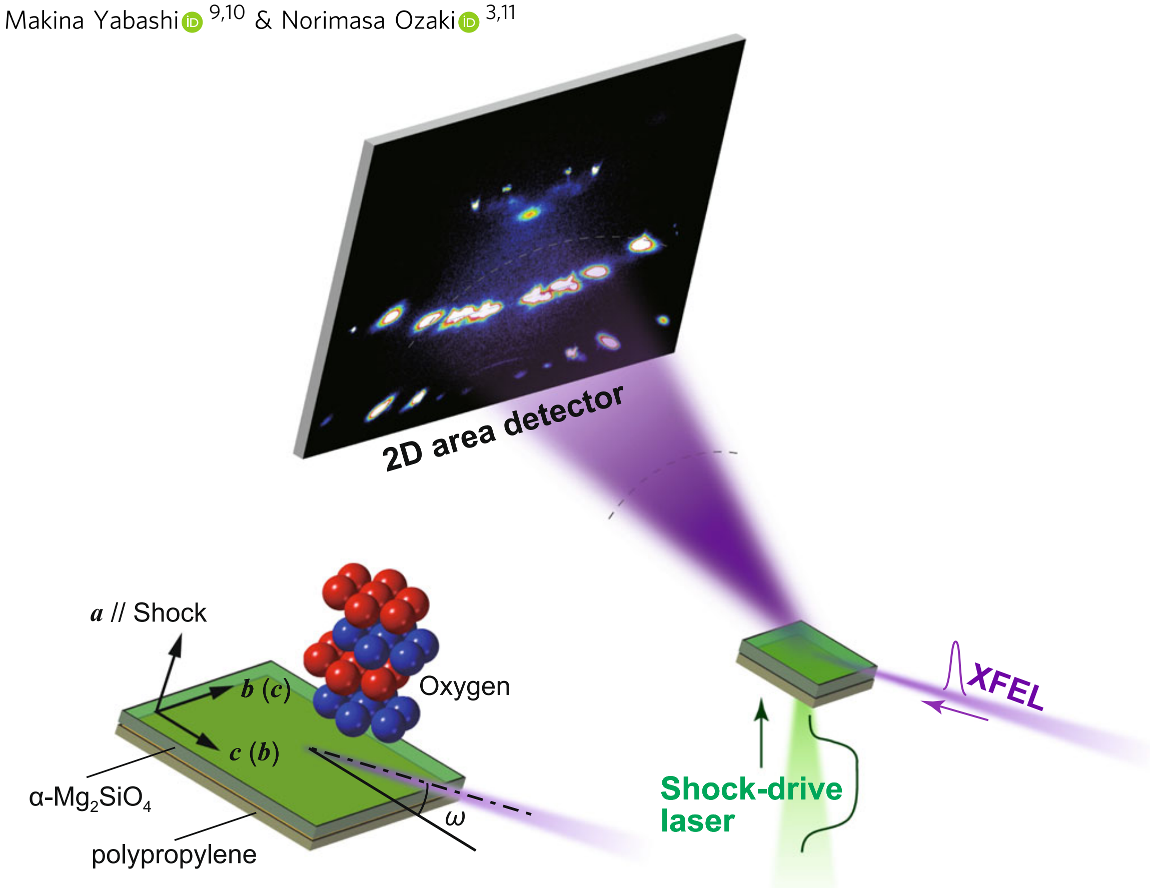
ARTICLE

Check for updates

https://doi.org/10.1038/s41467-021-24633-4 OPEN

Ultrafast olivine-ringwoodite transformation during shock compression

Takuo Okuchi[1,2,3✉], Yusuke Seto[4], Naotaka Tomioka[5], Takeshi Matsuoka[6], Bruno Albertazzi[3,7], Nicholas J. Hartley[3,8], Yuichi Inubushi[9,10], Kento Katagiri[3], Ryosuke Kodama[3,11], Tatiana A. Pikuz[3,6,12], Narangoo Purevjav[2], Kohei Miyanishi[10,11], Tomoko Sato[13], Toshimori Sekine[3,14], Keiichi Sueda[10], Kazuo A. Tanaka[3,15], Yoshinori Tange[9], Tadashi Togashi[9,10], Yuhei Umeda[1,2,3,11], Toshinori Yabuuchi[9,10], Makina Yabashi[9,10] & Norimasa Ozaki[3,11]

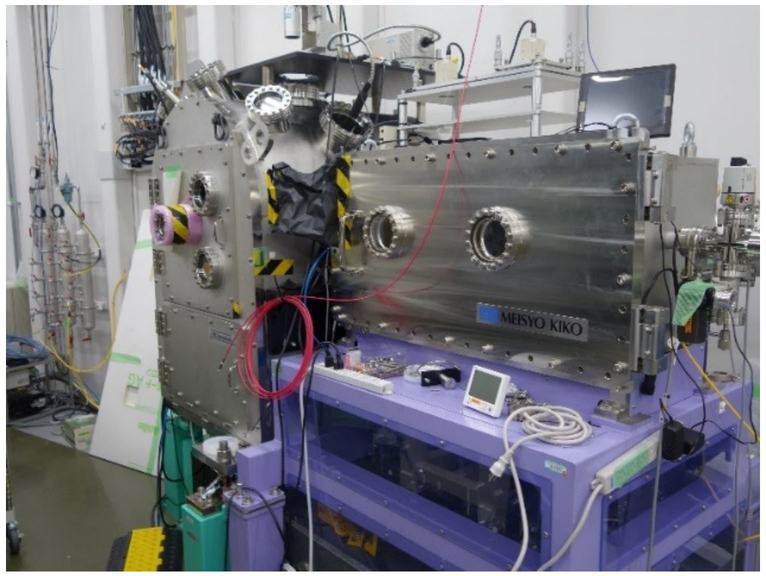


K. Katagiri et. al., *Phys. Rev. Lett.* 126, 175503 (2021).

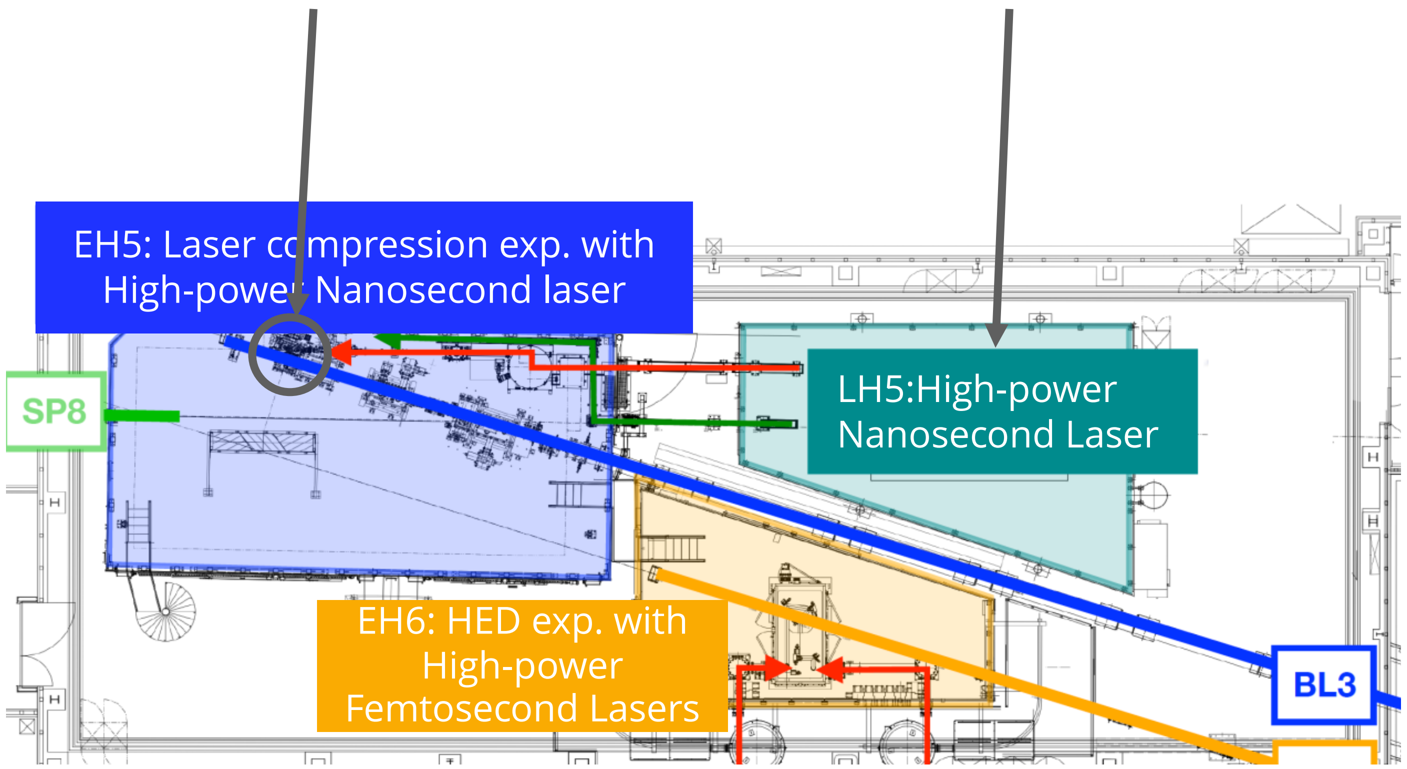
T. Okuchi et. al., *Nat. Commun.* 12, 4305 (2021).

Experimental platform with a high-power nanosecond laser

Experimental Chamber



Laser Bay



SACLA - SPring-8 Experimental Facility

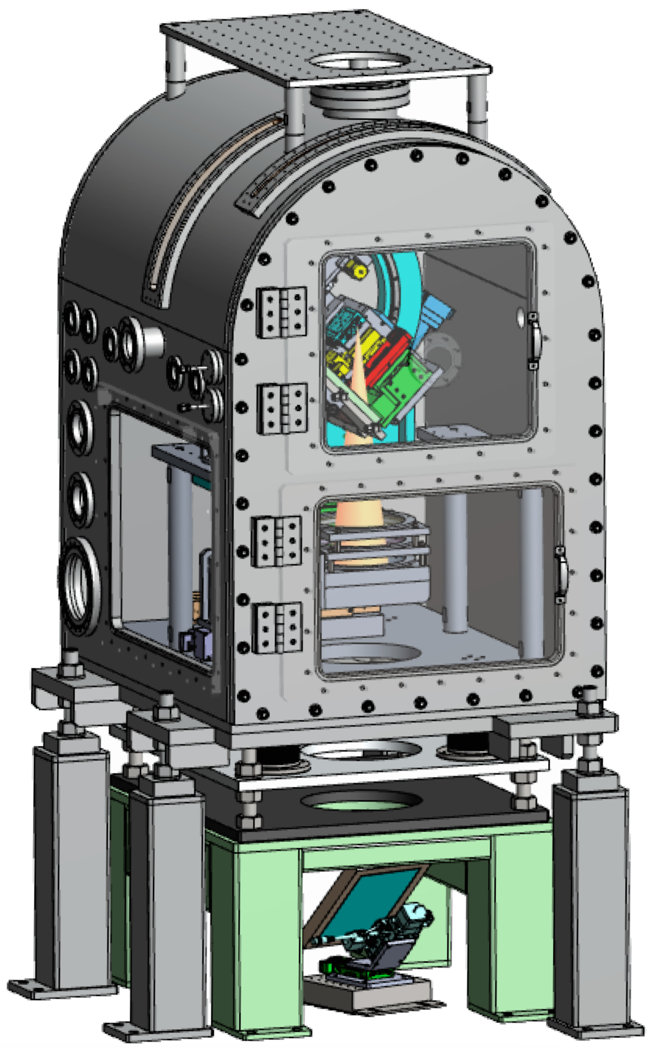
High-power nanosecond laser	
Pulse energy and duration	Up to 15 J@5ns on sample
Spot size (typical)	120/170/260 um FWHM
Wavelength	532 nm
Rep. rate	0.1Hz

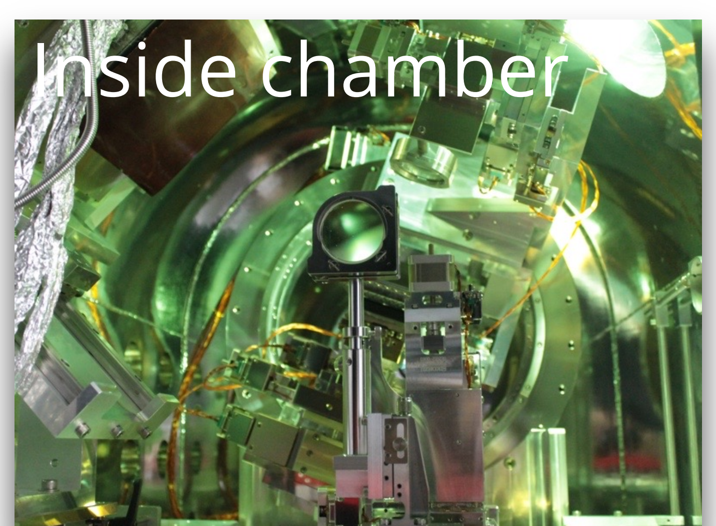
XFEL (BL3)	
Photon energy	4-20 keV
Band width	1.3×10^{-4}, $\sim 5 \times 10^{-3}$ (monochrome, pink beam)
Pulse energy	~600 μJ @10keV
Pulse duration	<10 fs
Rep. rate	30 Hz
Focusing optics	KB mirror for focusing (down to 0.5 μm, 1D or 2D)
Advanced operation	Self-seeding Two color Split-and-delay optics

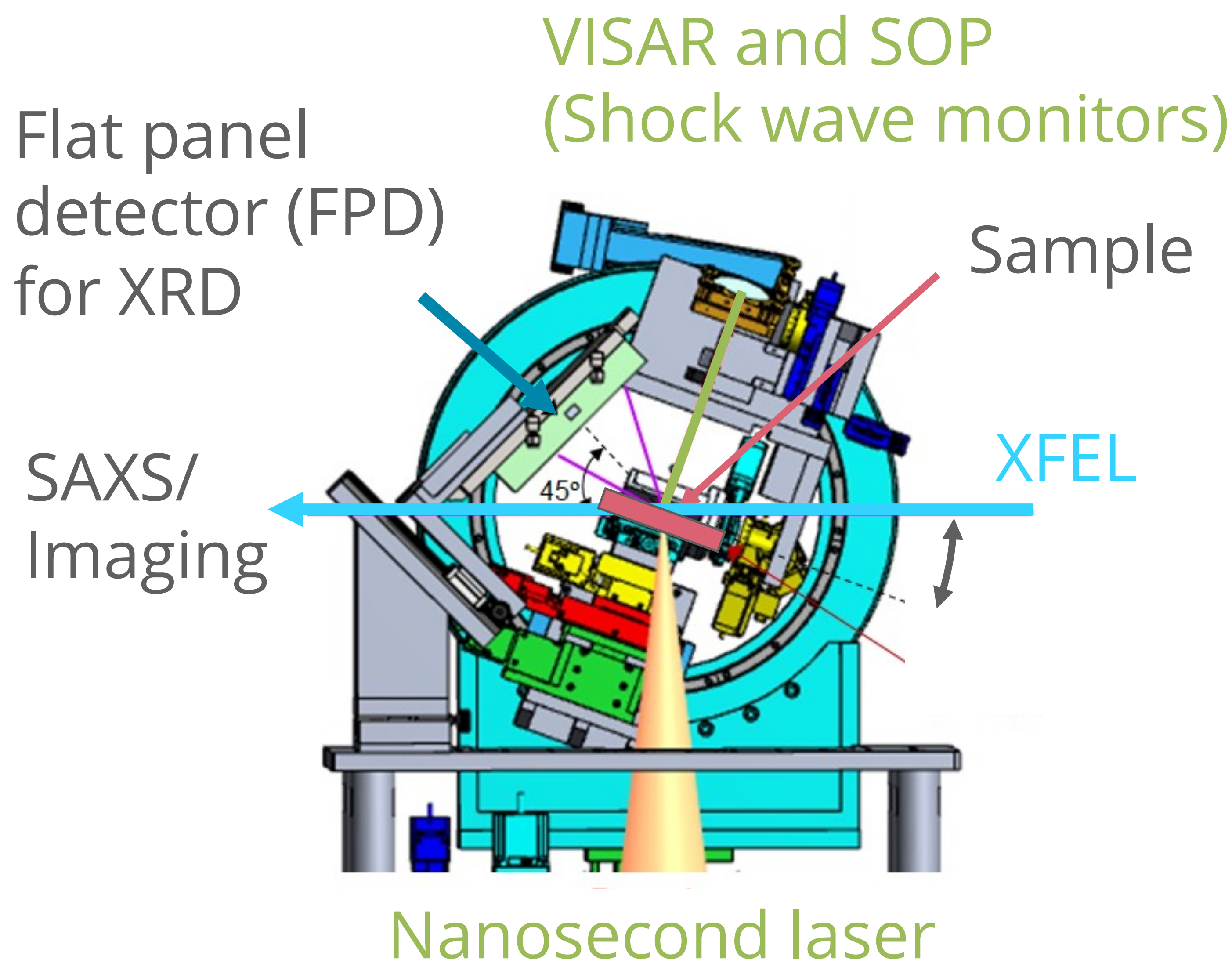
Platform was upgraded in 2018

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



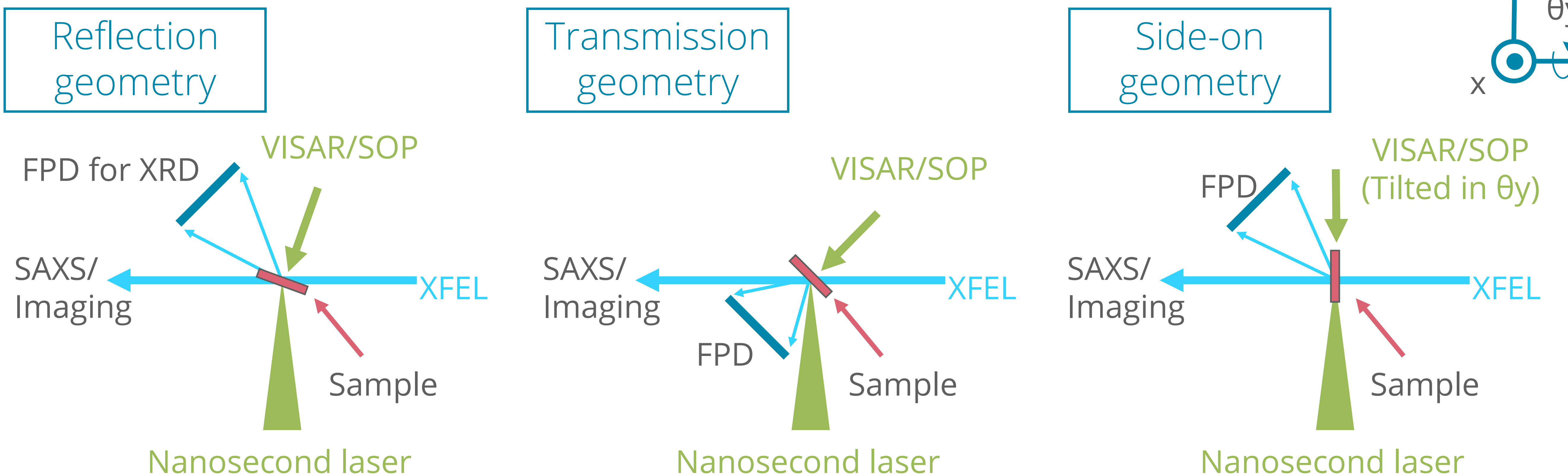


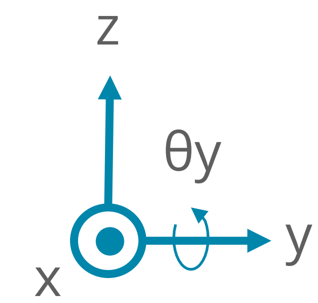


- VISAR and SOP are installed by Prof. Ozaki of Osaka Univ
- Configurations of XFEL and optical laser are fixed

Expansion of experimental configuration capability is in progress

Side view



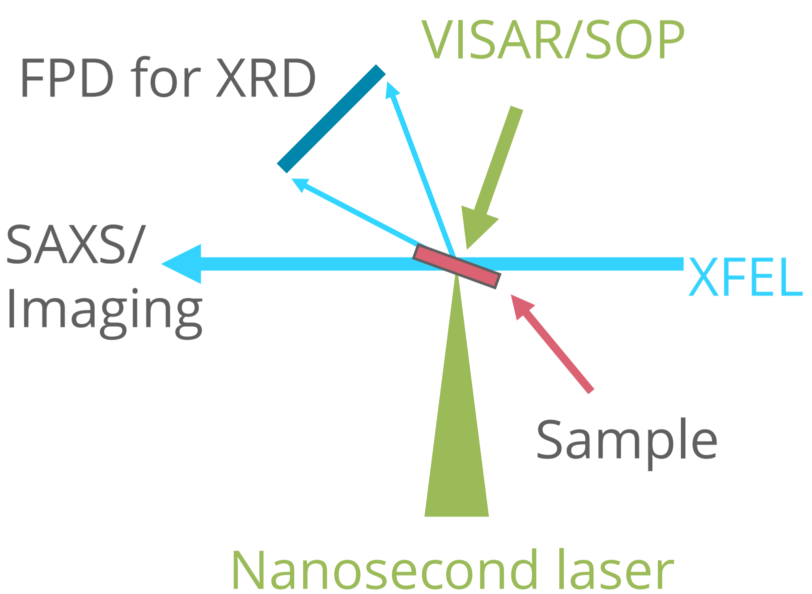


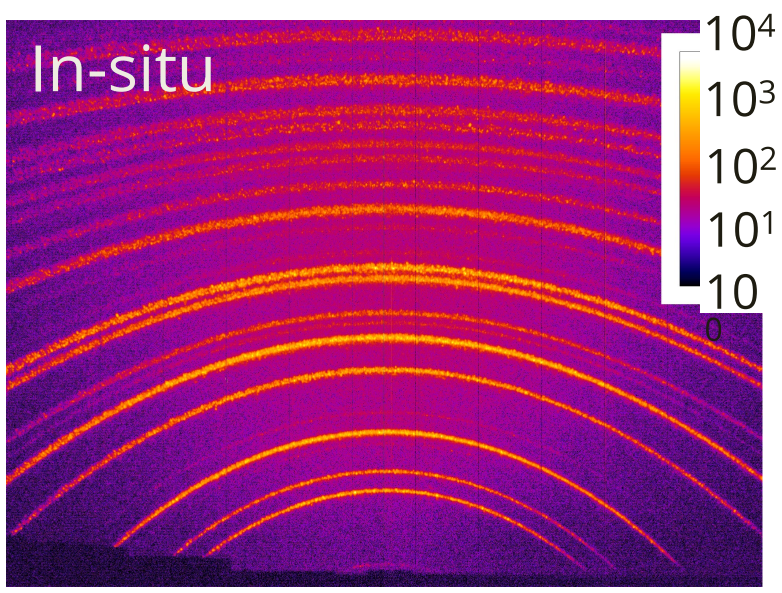
- Has been used for users' experiments since 2018B

- Has been tested

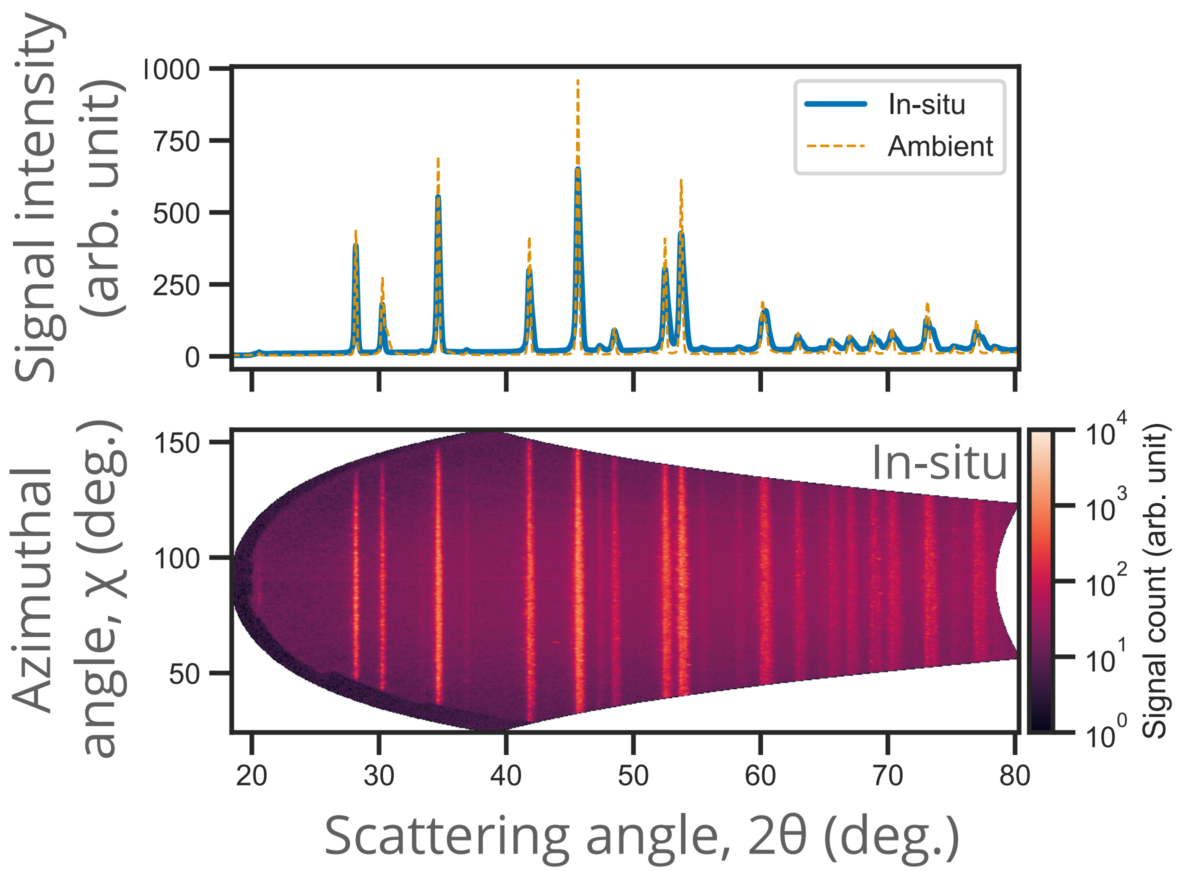
- Has been used for X-ray imaging experiments
- VISAR compatible with side-on geometry is under development with the cooperation of M. Koenig and B. Albertazzi of LULI Ecole polytechnique

Reflection geometry with the FPD at the top has been used for users' experiments since 2018B



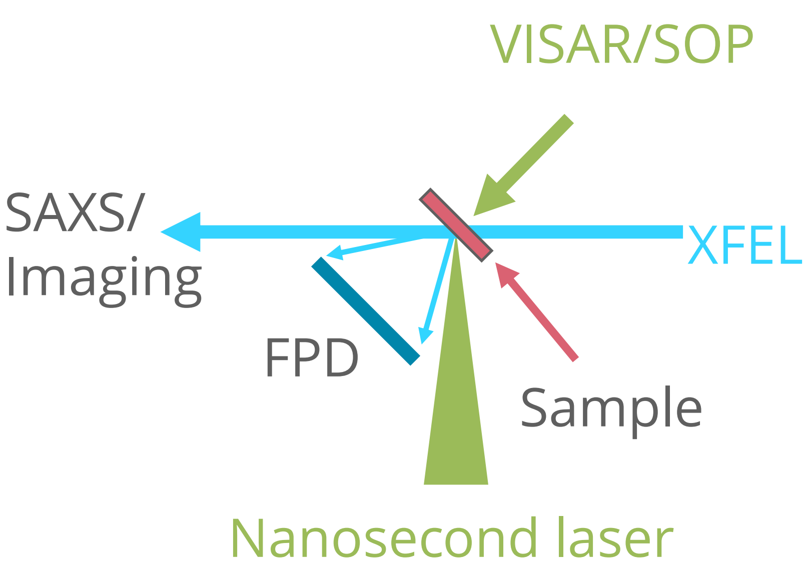


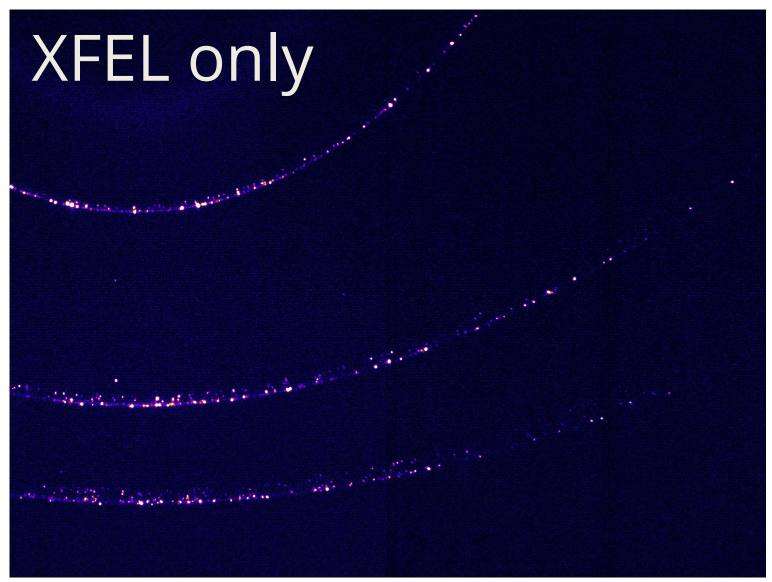
XRD pattern of corundum



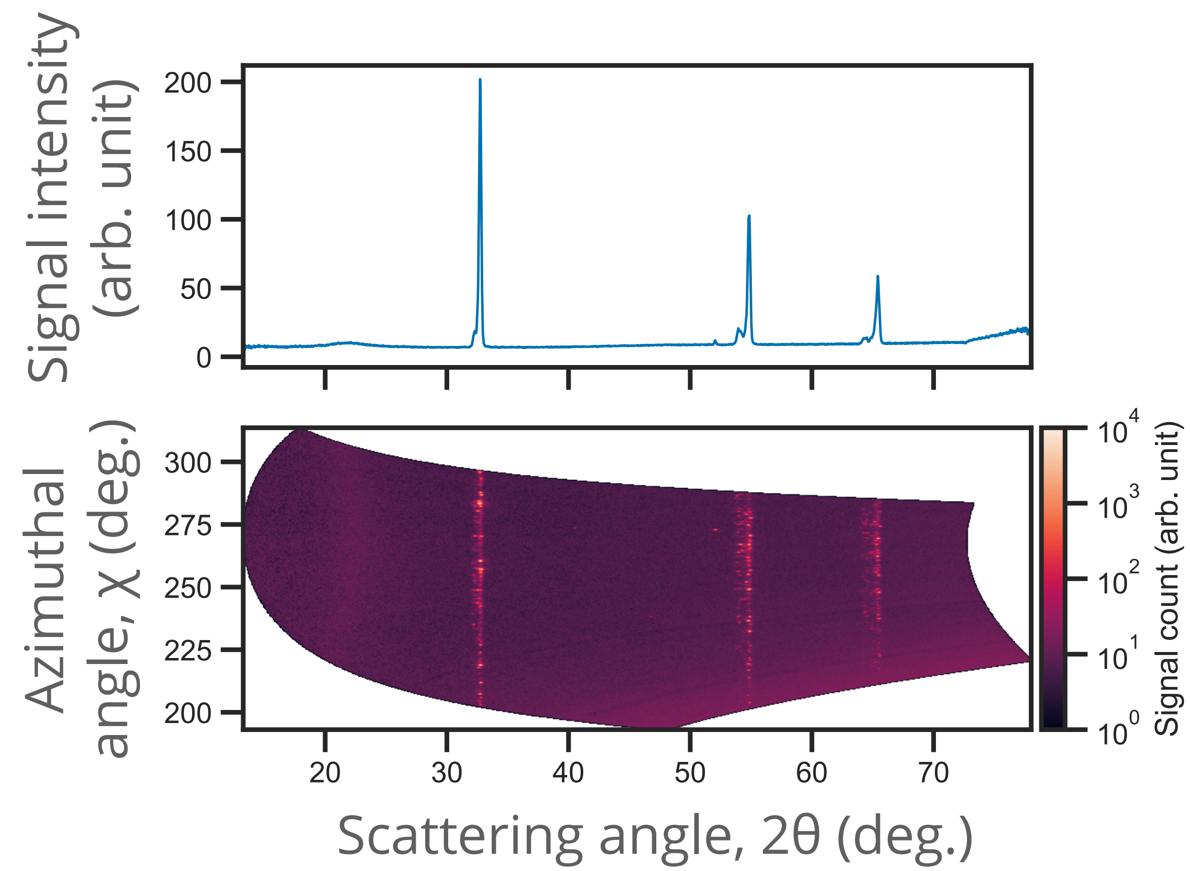
- Angular range
  - Scattering angle: 18–78 deg.
  - Azimuthal angle: 40–140 deg.
- Resolution of ~0.1 degrees

Transmission geometry with the FPD at the bottom has been tested



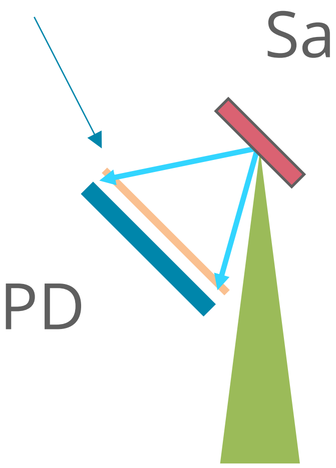


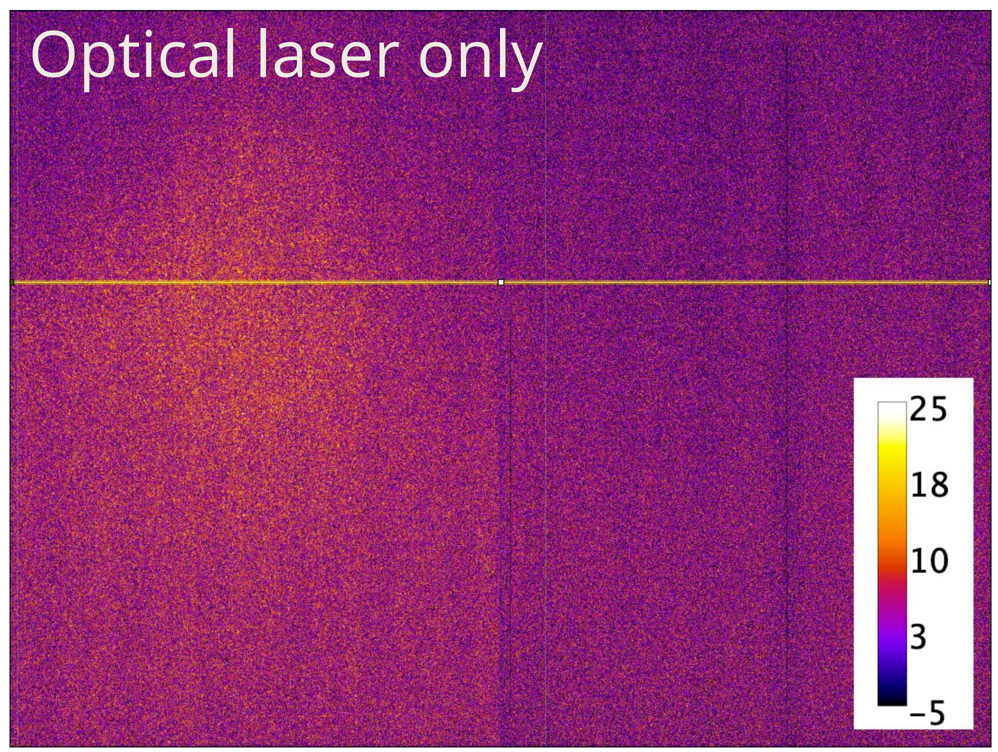
XRD pattern of Si
(NIST SRM 640e)



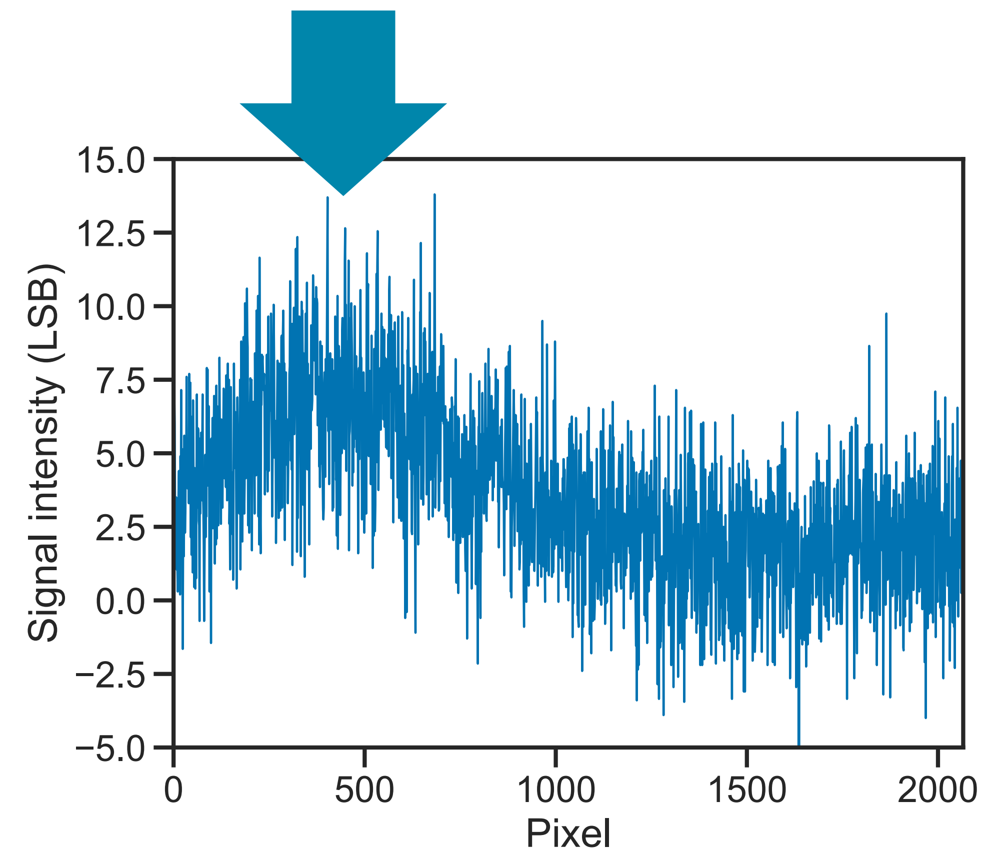
- Angular range
  - Scattering angle: 14–72 deg.
  - Azimuthal angle: 200–300 deg.
- Resolution of ~0.1 degrees

Noise from laser-plasma (a few counts) degrades XRD data with FPD at the bottom





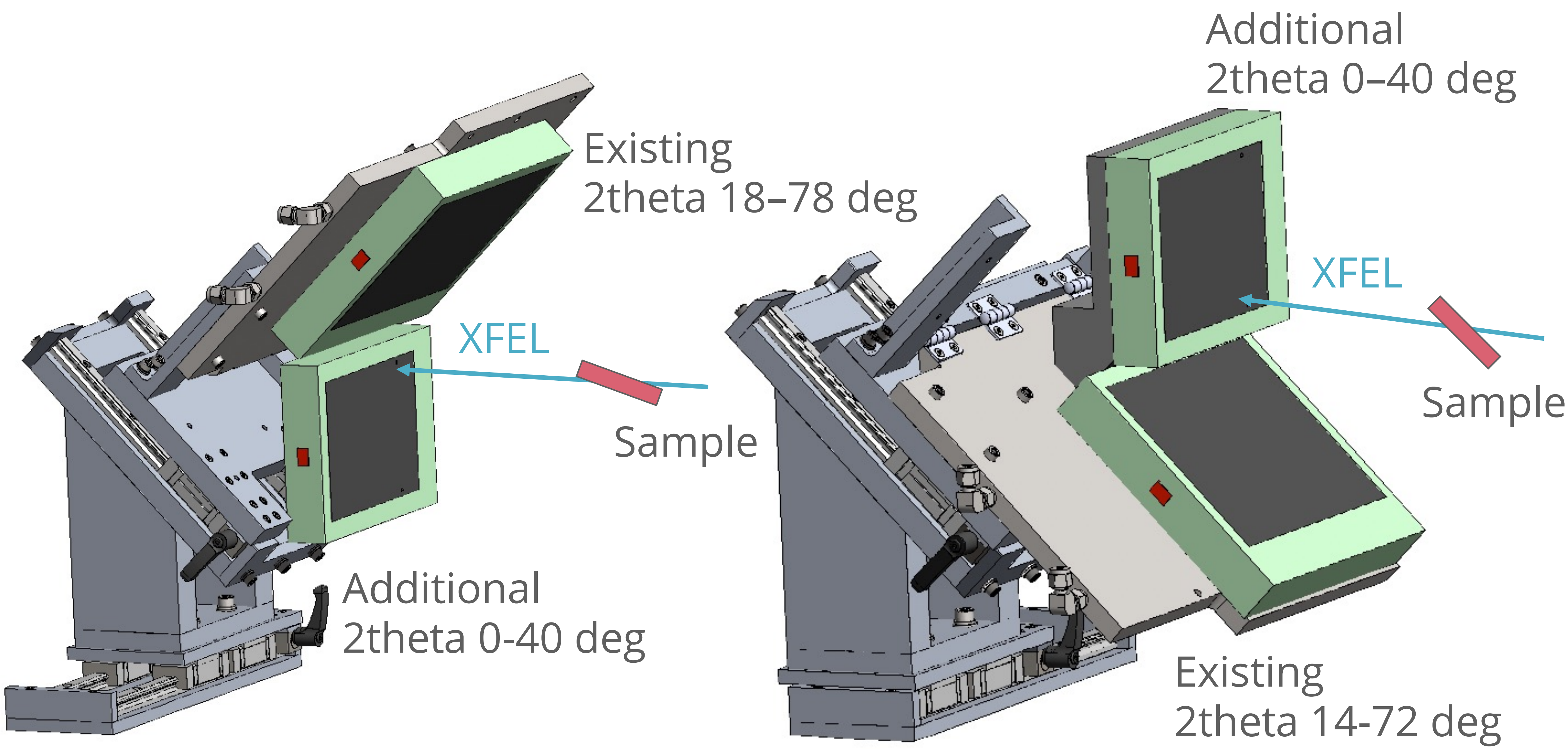
Noise from laser-plasma



10 px averaged profile

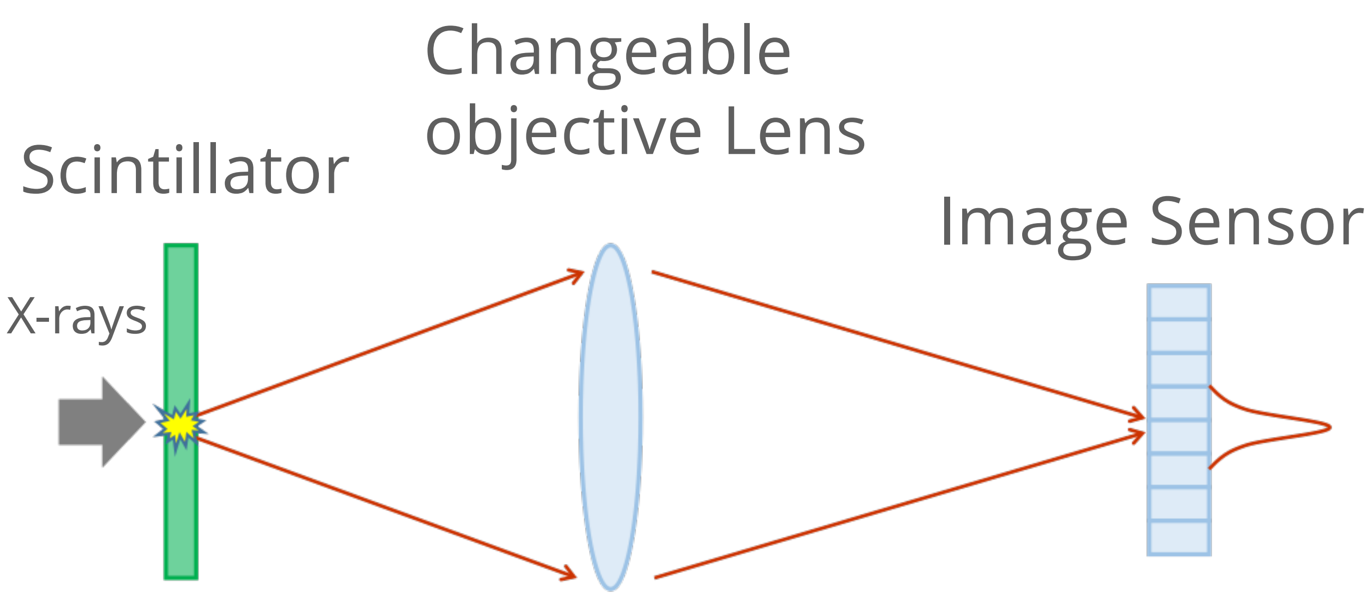
Needs to improve filtering

Installation of additional FPD to expand detection range is planned



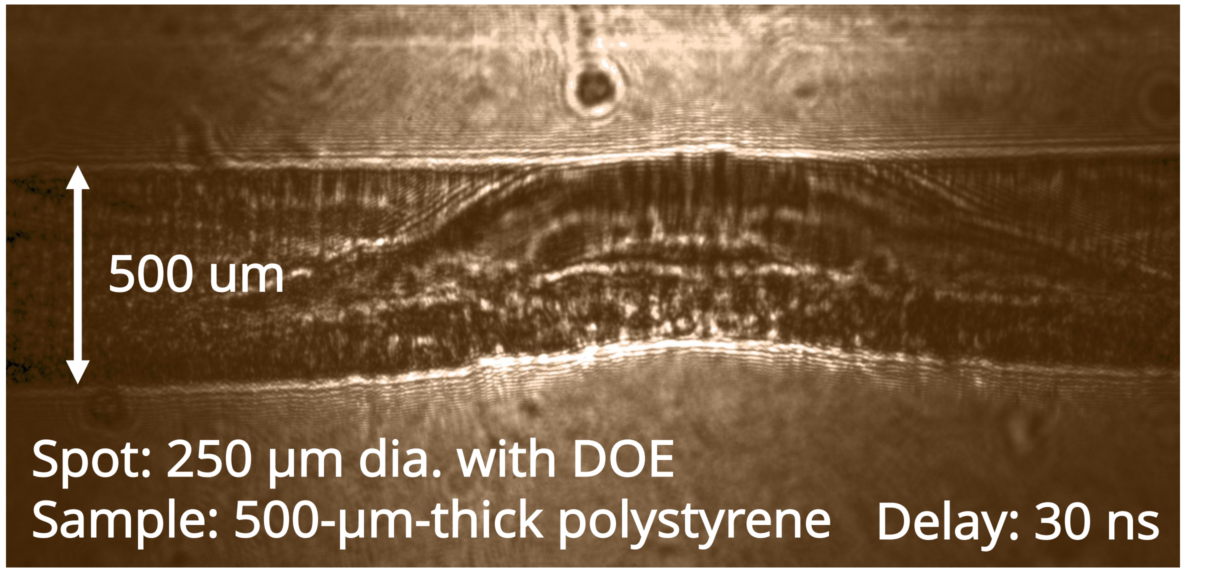
Preliminary design

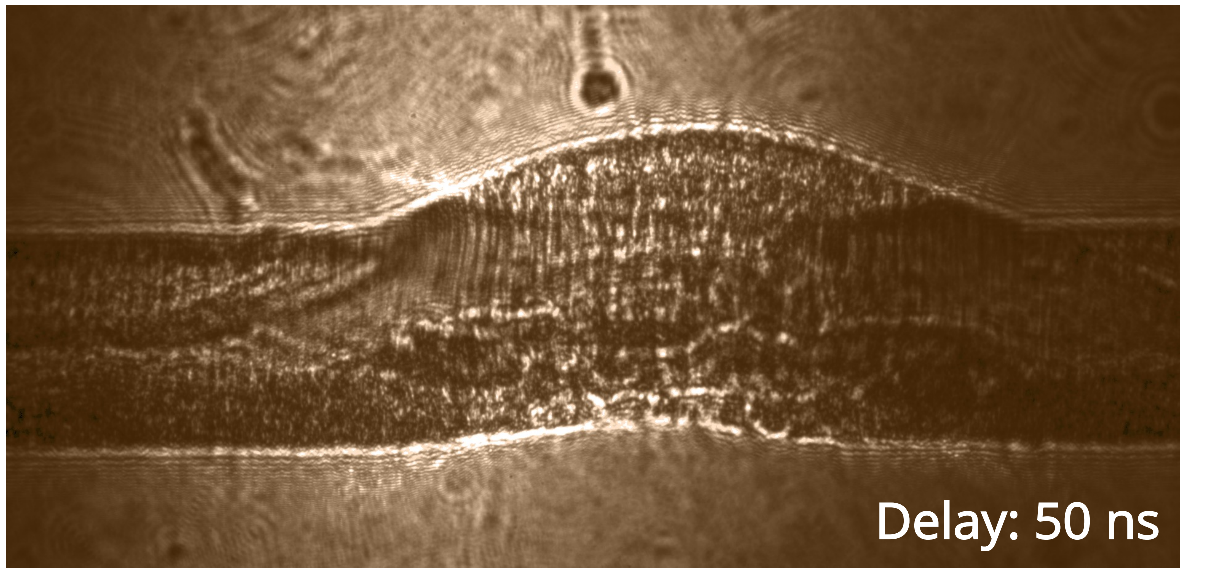
Combination of femtosecond bright X-ray pulse and high-resolution camera can capture fine images of shock propagation



1 um resolution with >1 mm field of view with 10x objective

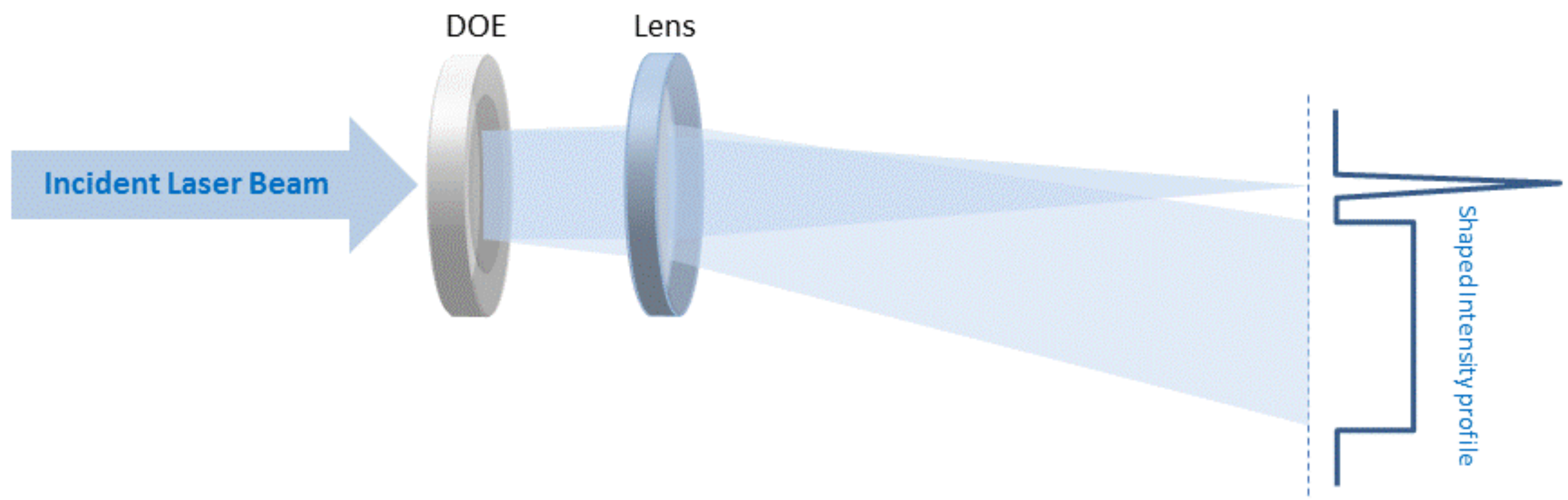
Shock wave propagation in plastic foil
(Objective lens: 10x)

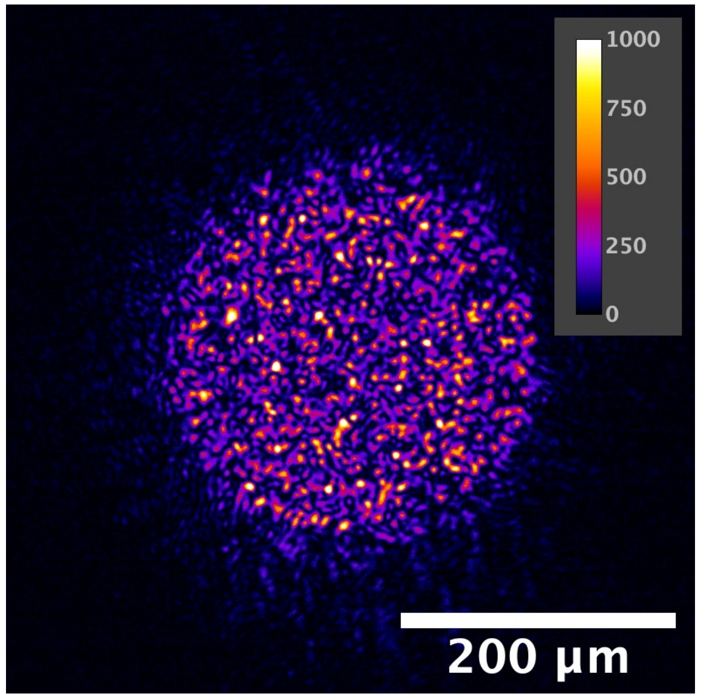


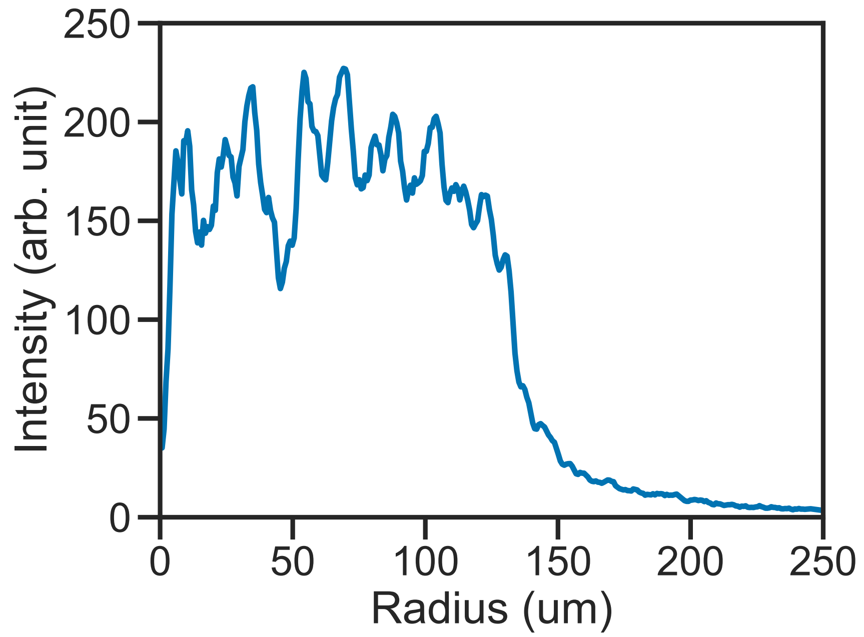


*Reference of the indirect x-ray imaging camera: T. Kameshima et al., Optics Letters 44, 1403 (2019).

Diffractive optical elements (DOEs), or phase plates, are available to provide smoothed quasi-flat top profiles







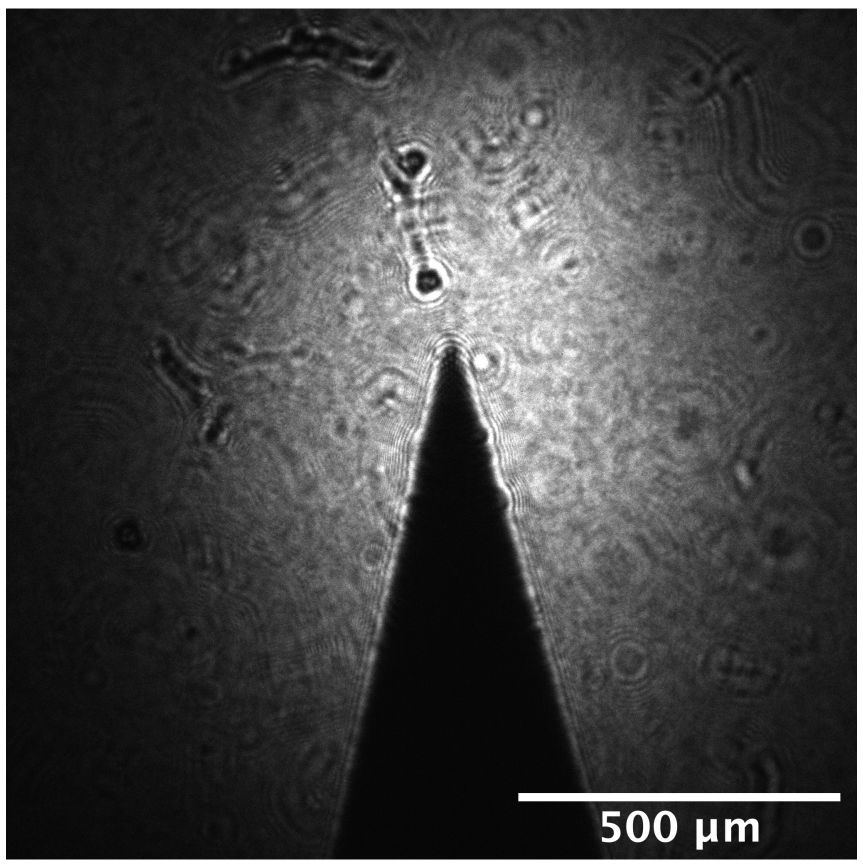
- DOEs for diameters of 120, 170 and 260 µm in FWHM are available

Additional DOEs for other spot sizes are under consideration.
Any inputs for the spot sizes are welcome.

Developed under the SACLA basic development program 2019 and 2020
by N. Ozaki/Osaka Univ., T. Okuchi/Kyoto Univ., and M. Koenig/LULI-CNRS.

XFEL beam size at sample position can be adjusted from 0.5 µm to ~1 mm (unfocused beam) with KB mirror

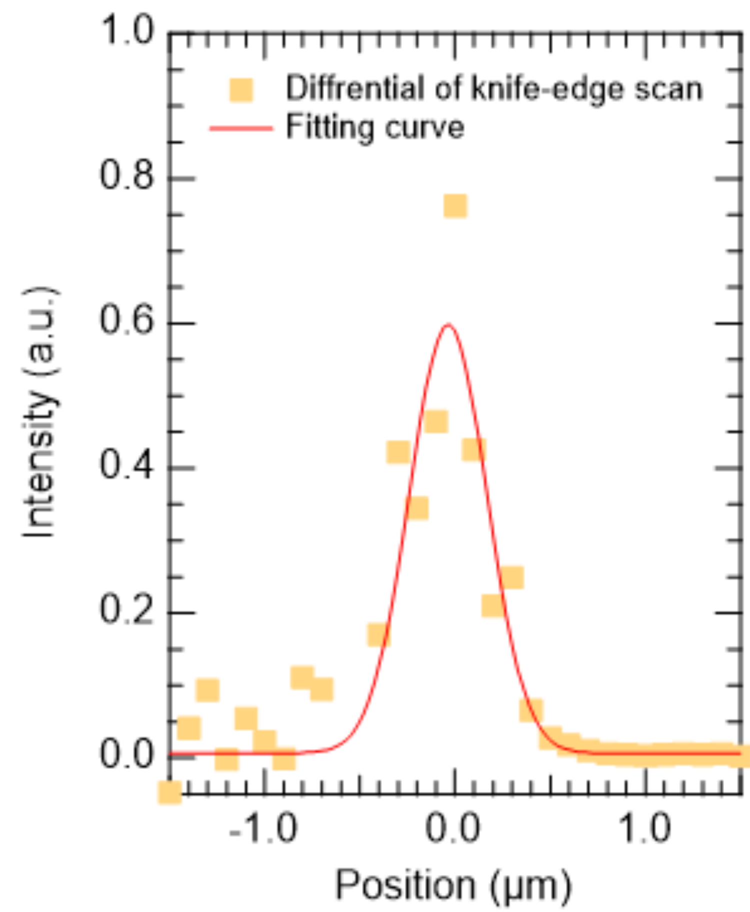
Unfocused beam



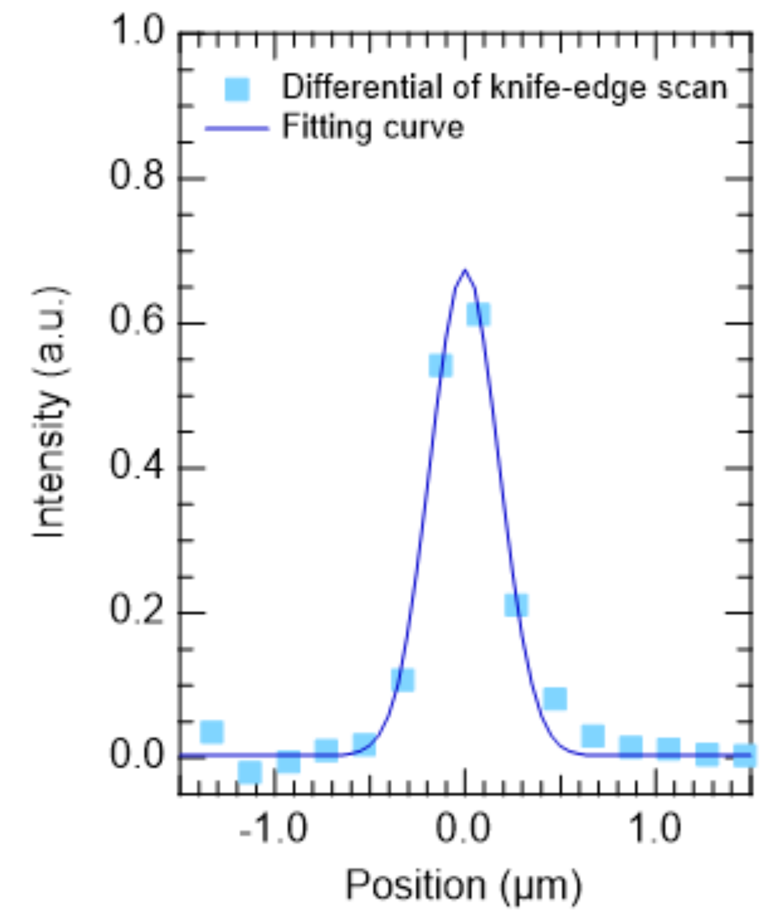
1000 µm in $1/e^2$
600 µm in FWHM

Focused beam

(a) 480 nm in vertical



(b) 430 nm in horizontal

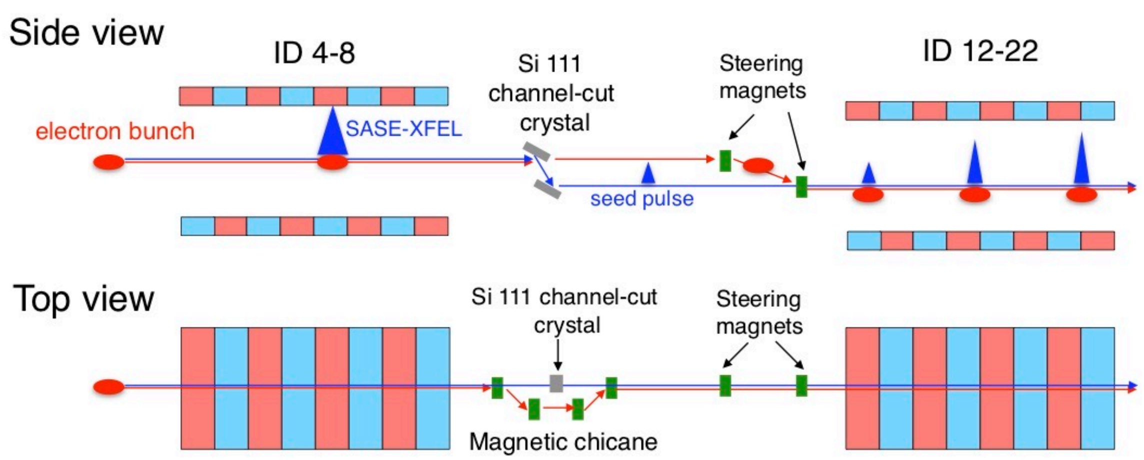


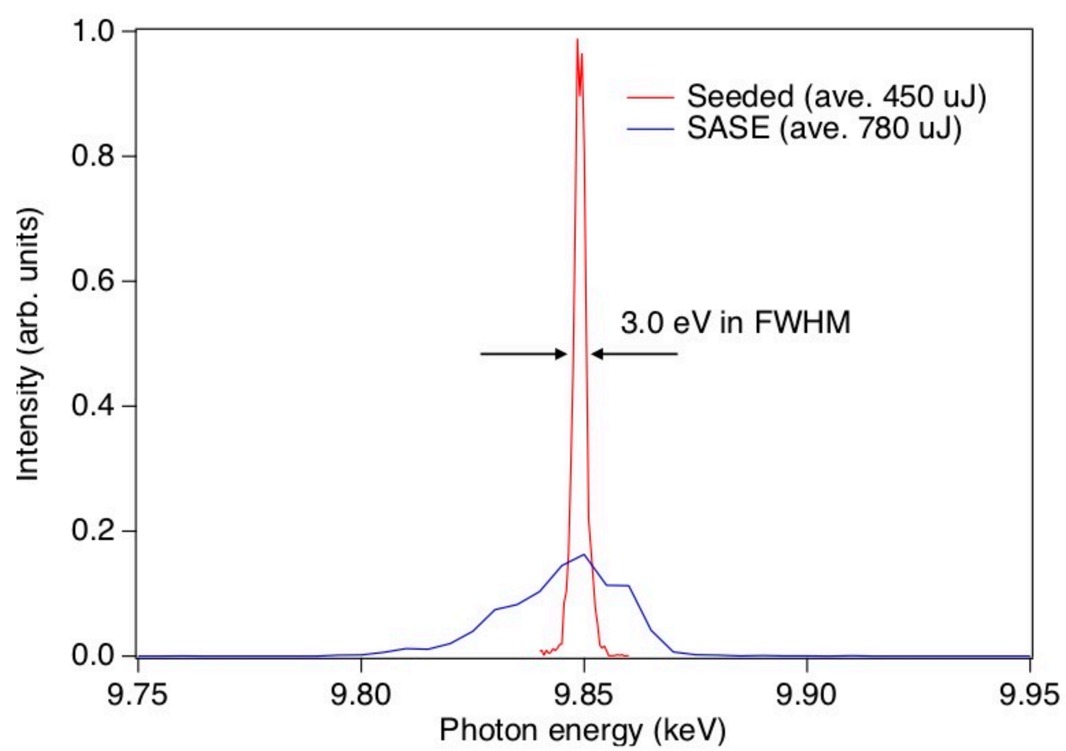
Down to ~0.5 µm
Typical beam size at sample for X-ray diffraction experiments is 10s µm

The KB mirror is compatible with photon energy of up to 15 keV

Advanced operations of BL3 are applicable to the platform

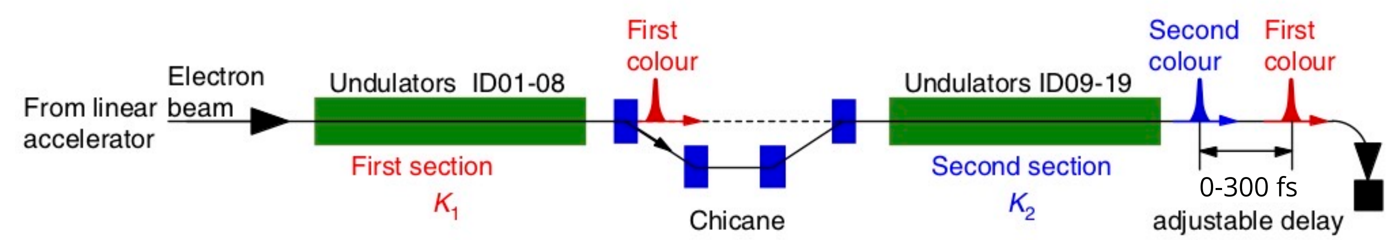
Self-seeded XFELs

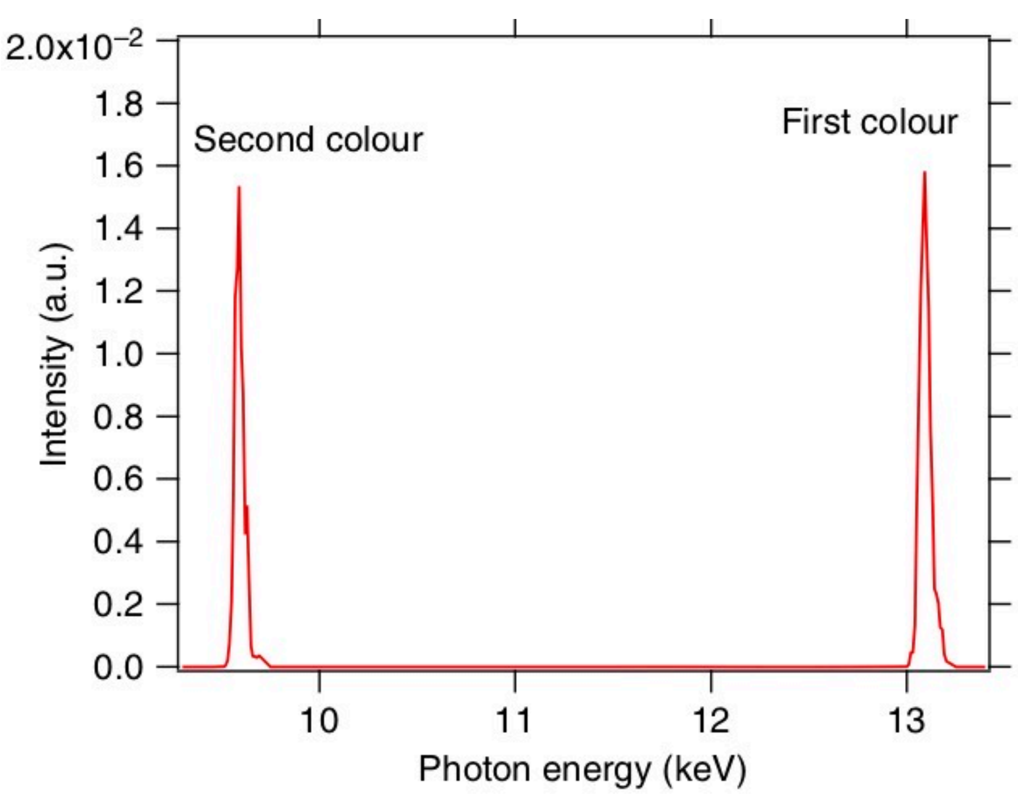




I. Inoue et. al., Nat. Photonics 13, 319 (2019).

Two-color XFELs

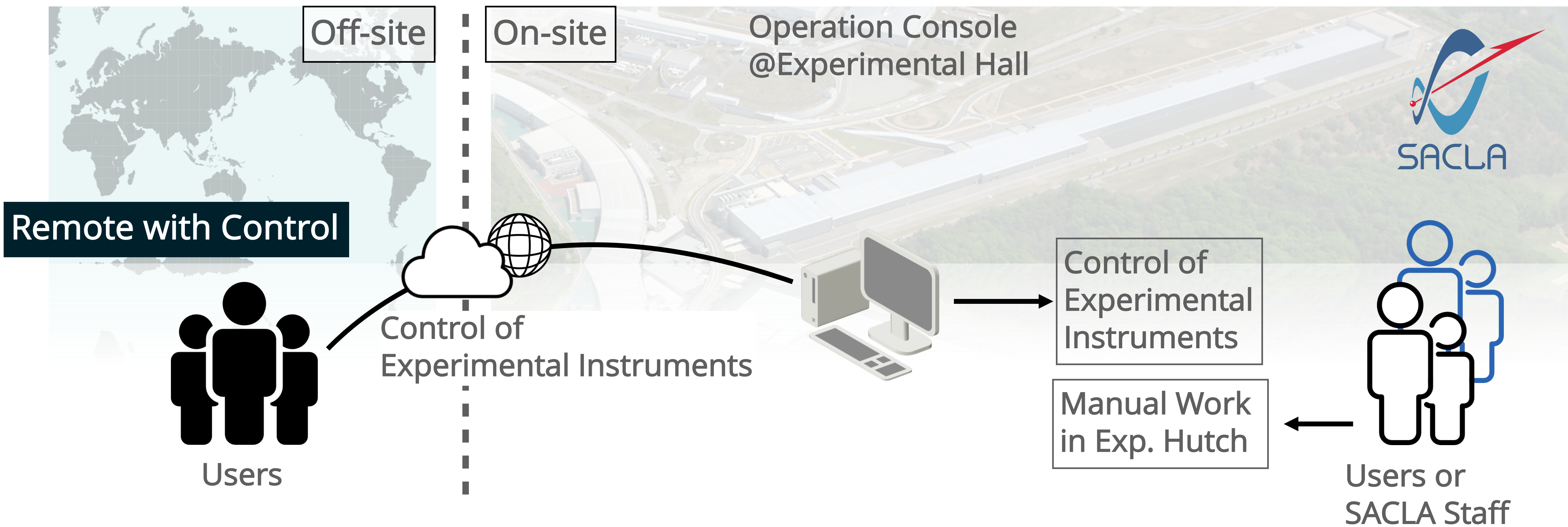




T. Hara et al., Nat. Commun. 4 (2013).
I. Inoue et al., PNAS 113 (2016).

See Poster “Overview of SACLA Beamlines (BL1, 2, 3)”

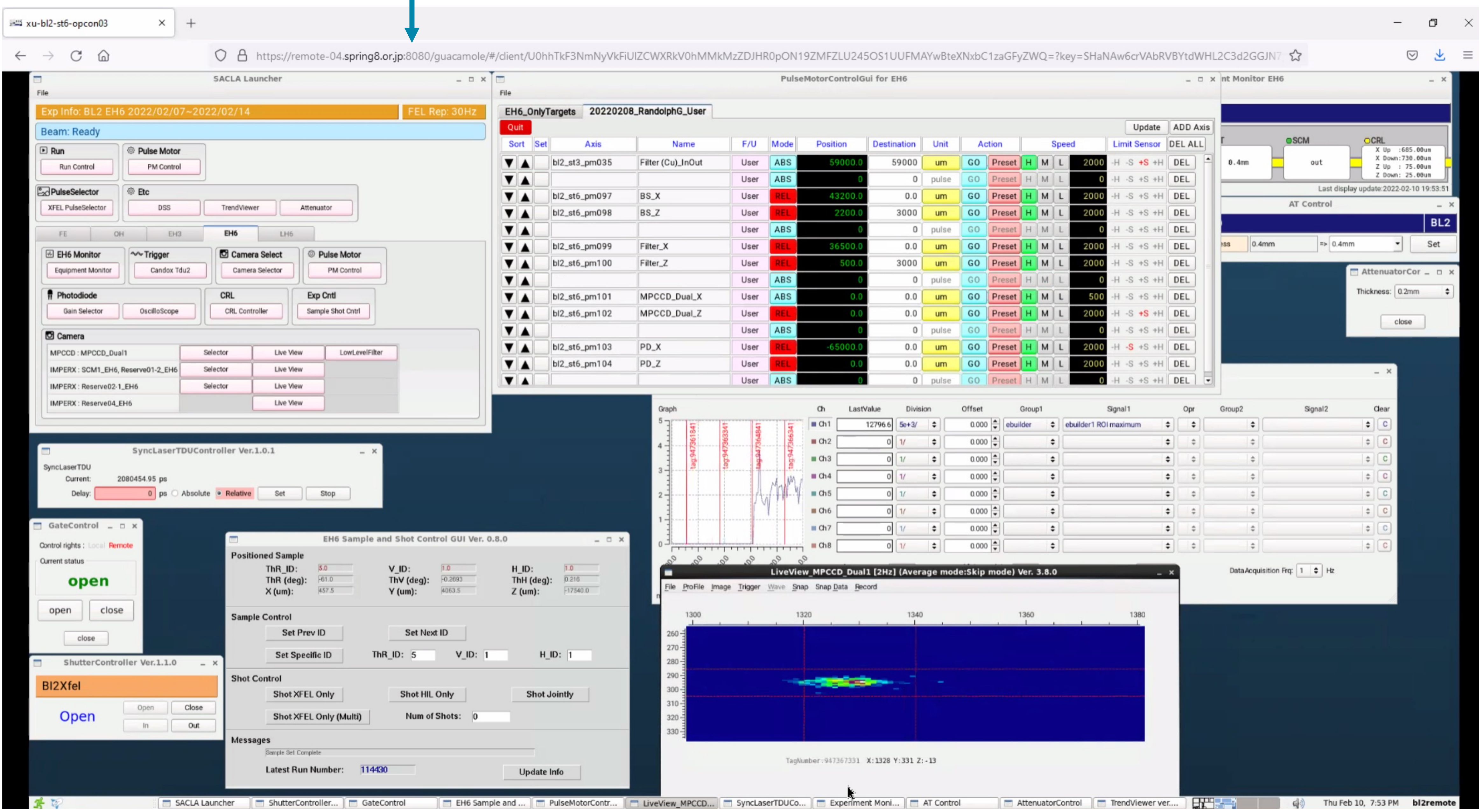
Remote-control system allows to control experimental instruments from outside of SACLA



- Users can control experimental instruments (RUN, stages, shutters, detectors) from off-site
- On-site participants handle on-site work, e.g., sample change

First users' experiments with the remote-control system have been performed at high-power fs laser platform

Remotely accessed with web browser



Users have remotely accessed to SACLA beamline instruments and HPC system from European XFEL, HZDR (Germany) and Imperial College London (UK).

Applicable to nanosecond laser platform

Contact beamline staff if you have any ideas, plans

Major Developments

The SACLA/SPring-8 Basic Development Program invites proposals from a wide variety of users for the development of new instruments to promote innovative science leveraging SACLA's unique capabilities.

[Call of the program open/close: Dec./Feb. (usually)]

[Basic Development Program 2021 session will be held tomorrow]

Minor Developments

Minor developments could be carried out for users' experiments.

Please contact beamline staff well in advance of your proposal submission.

Summary

- Experimental platform with high-power nanosecond laser is available for users' experiments at SACLA
- Chamber/Configurations
  - The experimental chamber is designed for X-ray diffraction, X-ray imaging, and small-angle X-ray scattering experiments of laser-compressed materials
  - Expansion of experimental configuration capability is in progress
  - Installation of additional detector for XRD to expand detection range is planned
- High-power nanosecond laser
  - Recent pulse energy is up to 15 J on sample in 5 ns quasi-square
- XFEL
  - XFEL beam size at sample position can be adjusted from 0.5 μm to ~1 mm with KB mirror
  - Advanced operations of BL3 are applicable
- First users' experiments with the remote-control system has been performed