Capability, updates, and development plans of the experimental platform with highpower 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 highpower nanosecond laser and XFEL at SACLA"



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



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



Recent activities at the high-power nanosecond laser platform



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OPEN

Evidence of shock-compressed stishovite above 300 GPa

Markus O. Schoelmerich¹[⊠], Thomas Tschentscher¹, Shrikant Bhat², Cindy A. Bolme³, Eric Cunningham⁴, Robert Farla², Eric Galtier⁴, Arianna E. Gleason⁴, Marion Harmand⁵, Yuichi Inubushi^{6,7}, Kento Katagiri⁸, Kohei Miyanishi⁶, Bob Nagler⁴, Norimasa Ozaki⁸, Thomas R. Preston¹, Ronald Redmer⁹, Ray F. Smith¹⁰, Tsubasa Tobase¹¹, Tadashi Togashi^{6,7}, Sally J. Tracy¹², Yuhei Umeda⁸, Lennart Wollenweber¹, Toshinori Yabuuchi^{6,7}, Ulf Zastrau¹ & Karen Appel¹



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4

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

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

G. Rigon ^{1⊠}, B. Albertazzi¹, T. Pikuz ^{2,3}, P. Mabey¹, V. Bouffetier⁴, N. Ozaki ^{5,6}, T. Vinci ¹, F. Barbato ⁴, E. Falize⁷, Y. Inubushi^{8,9}, N. Kamimura⁵, K. Katagiri ⁵, S. Makarov^{3,10}, M. J.-E. Manuel¹¹, K. Miyanishi ⁹, S. Pikuz ^{3,12}, O. Poujade^{7,13}, K. Sueda⁹, T. Togashi^{8,9}, Y. Umeda^{5,14}, M. Yabashi ^{8,9}, T. Yabuuchi ^{8,9}, G. Gregori¹⁵, R. Kodama⁵, A. Casner ^{4,16} & M. Koenig^{1,5}





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

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^(b),^{1,2,*} N. Ozaki^(b),^{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^(b),² K. Sueda,⁷ Y. Tange^(b),⁶ T. Togashi,^{6,7} Y. Umeda^(b),¹² M. Yabashi^(b),^{6,7} T. Yabuuchi^(b),^{6,7} and R. Kodama^{1,2}



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



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5

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

Ultrafast olivine-ringwoodite transformation during shock compression

Takuo Okuchi [®] ^{1,2,3™}, Yusuke Seto⁴, Naotaka Tomioka [®] ⁵, Takeshi Matsuoka⁶, 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 Purevjav², Kohei Miyanishi [®] ^{10,11}, Tomoko Sato¹³, Toshimori Sekine^{3,14}, Keiichi Sueda¹⁰, 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}



Experimental platform with a high-power nanosecond laser

Experimental Chamber	Laser Bay	High-power nanosecond laser							
		Pulse energy and duration	Up to 15 J@5ns on sample						
		Spot size (typical)	120/170/260 um FWHM						
	HAMAMATSI	Wavelength	532 nm						
		Rep. rate	0.1Hz						
		XFEL (BL3)							
		Photon energy	4-20 keV						
EH5: Laser cc mpression exp. with		Band width	1.3 x 10 ⁻⁴ , ~5 x 10 ⁻³ (monochrome, pink beam)						
High-power Nanosecond laser		Pulse energy	~600 µJ @10keV						
SP8	LH5:High-power	Pulse duration	<10 fs						
Figh-power Femtosecond Lasers SACLA - SPring-8 Experimenta		Rep. rate	30 Hz						
		Focusing optics	KB mirror for focusing (down to 0.5 μm, 1D or 2E						
	nental Facility	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

7

Expansion of experimental configuration capability is in progress

Side view



K. Miyanishi, SACLA Users Meeting 2022, 2nd May 2022

Ecole polytechnique

cooperation of M. Koenig

and B. Albertazzi of LULI

Ζ

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



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



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



Needs to improve filtering

Installation of additional FPD to expand detection range is planned



Preliminary design

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



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





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

*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



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. K. Miyanishi, SACLA Users Meeting 2022, 2nd May 2022

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

Soo μm



1000 µm in 1/e² 600 µm in FWHM

Unfocused beam

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



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

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

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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.



- 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 lasercompressed 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