High Power Lasers and HEDS Stations at SACLA

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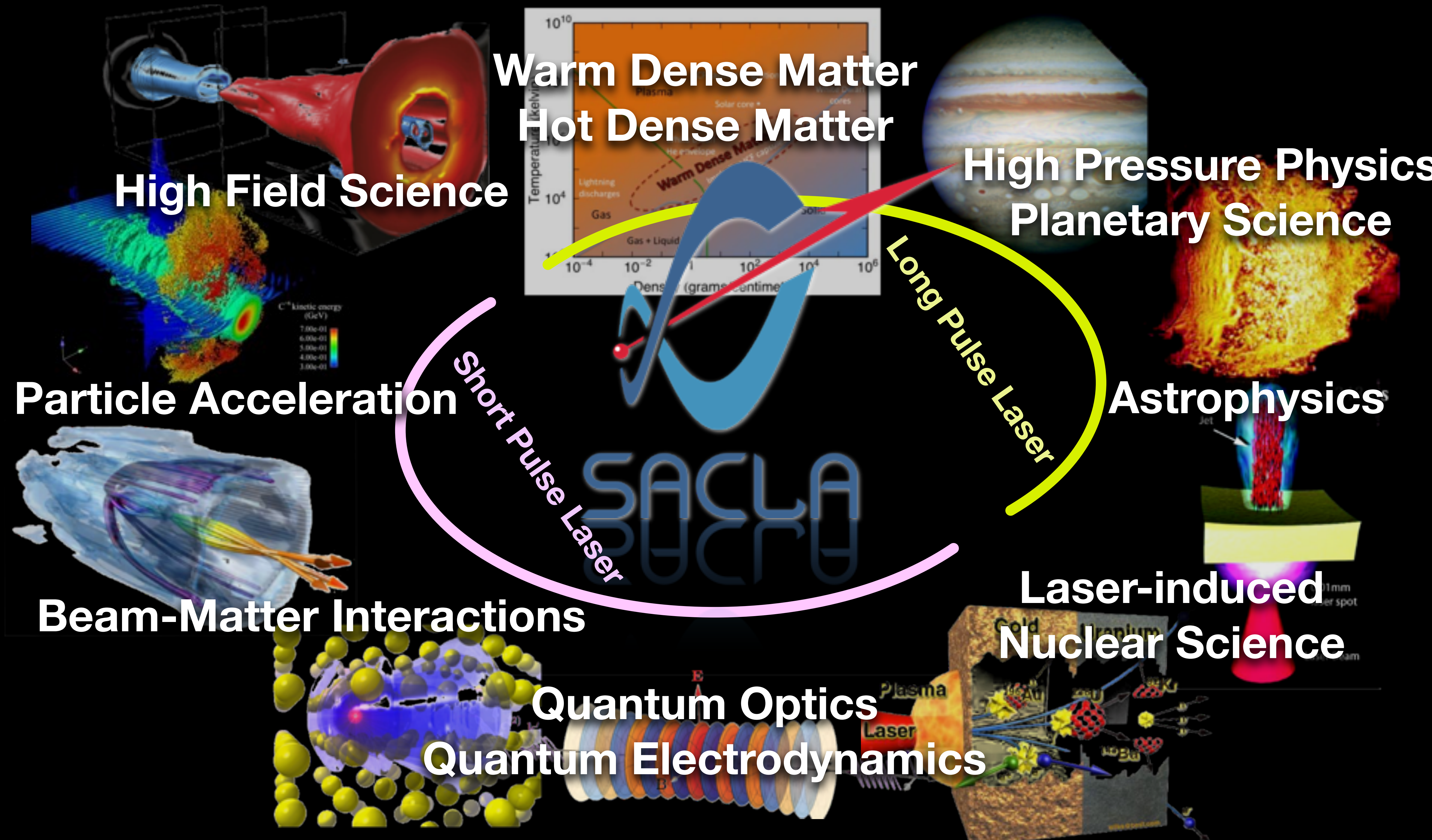
Outline

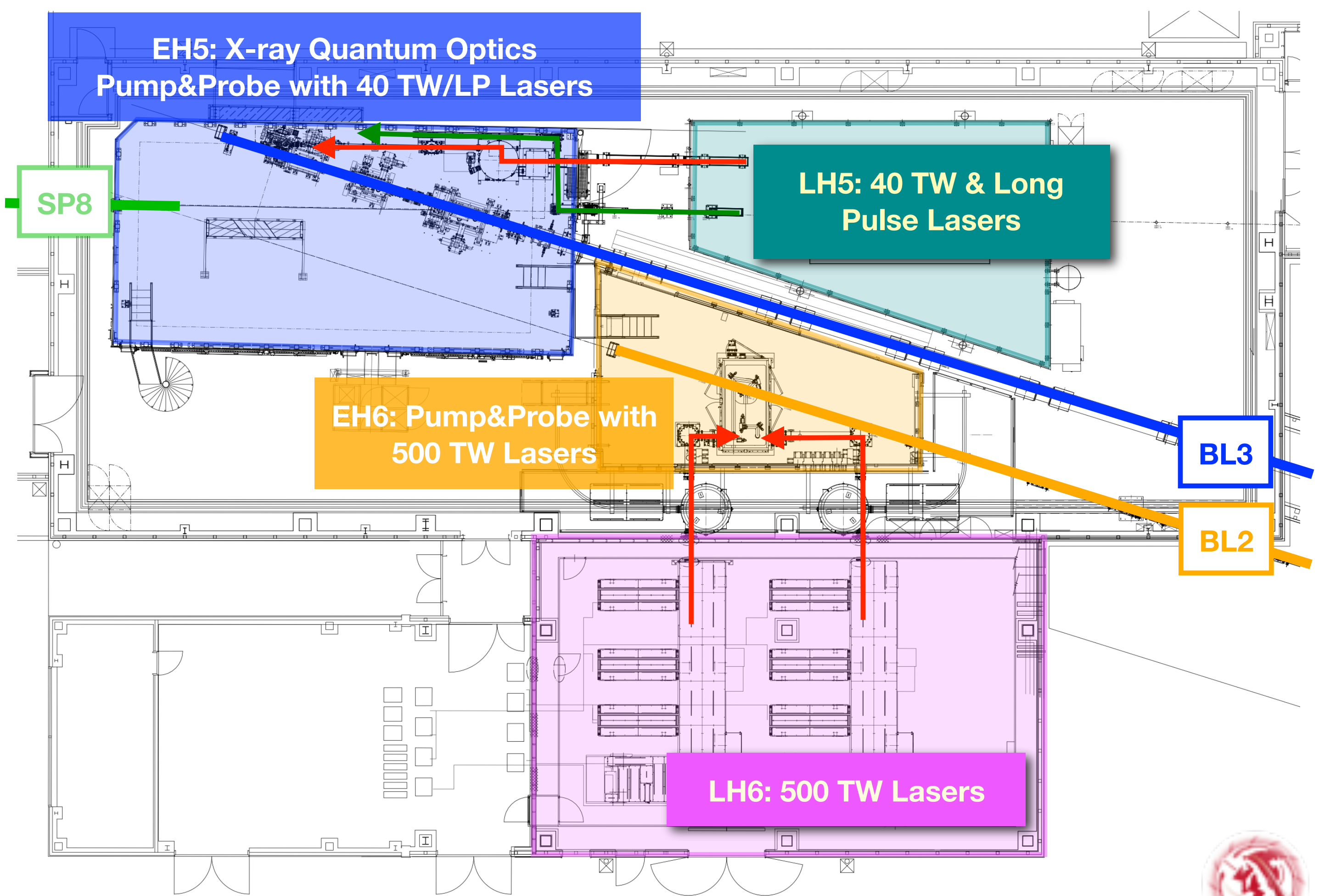
- **Introduction**
  - High Energy Density Sciences (HEDS) using high power lasers and XFELs
- **Experimental Station using XFEL and High-pulse Energy Laser**
  - Experimental platform in EH5 with a nano-second, high-pulse energy laser
- **Experimental Station using XFEL and High-intensity Lasers**
  - Experimental platform in EH6 with femto-second, high-intensity energy lasers
- **Summary**

Combination of high power laser and XFEL opens new frontiers of HEDS



Refs: A. Flacco et al, Nat. Phys., 11, 409 (2015), A. A. Correa et al, Phys. Rev. Lett., 108, 213201 (2012), F. Karbstein et al, Phys. Rev. D, 92, 071301(R) (2015), D. Hammer et al, Basic Research Needs for High Energy Density Laboratory Physics (2009), S. C. Cowley et al, Plasma Science: Advancing Knowledge in the National Interest (2007), R. C. Davidson et al, Frontiers in High Energy Density Physics: the X-games of Contemporary Science (2003), Science@NASA Headline News: http://science.nasa.gov/science-news/science-at-nasa/1999/ast24mar99_1.

HEDS Stations at SACLA



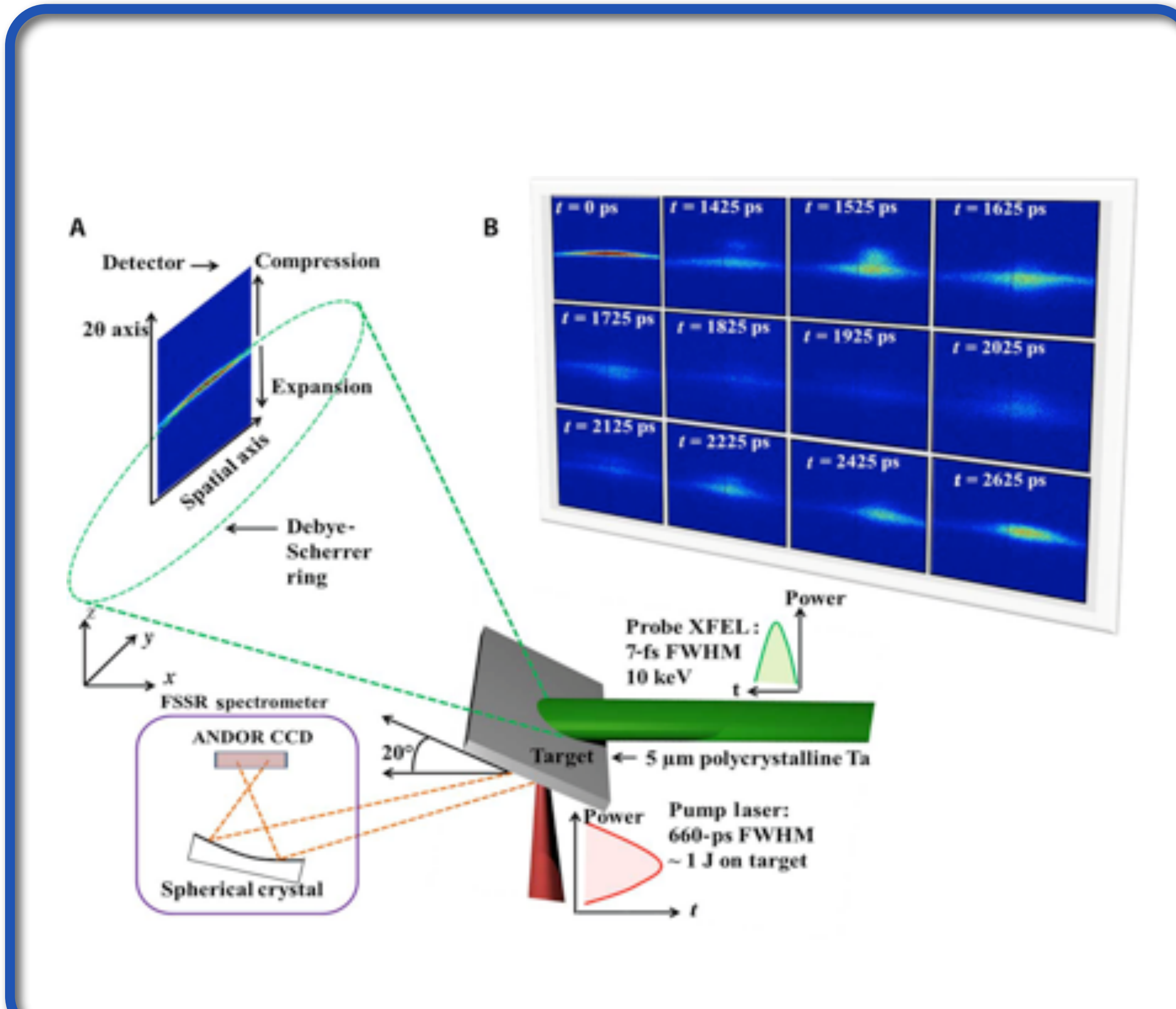
	40 TW Laser	500 TW Laser x2	Long Pulse Laser
Status	Operational	Under Commissioning	Operational
Pulse Energy	~1 J	~10 J	~ 10 J (to be upgraded)
Pulse Duration	~25 fs	~25 fs	~4 ns
Max. Rep. Rate	10 Hz	1 Hz	0.1 Hz
SACLA EH	EH5	EH6	EH5

HERMES HAPs

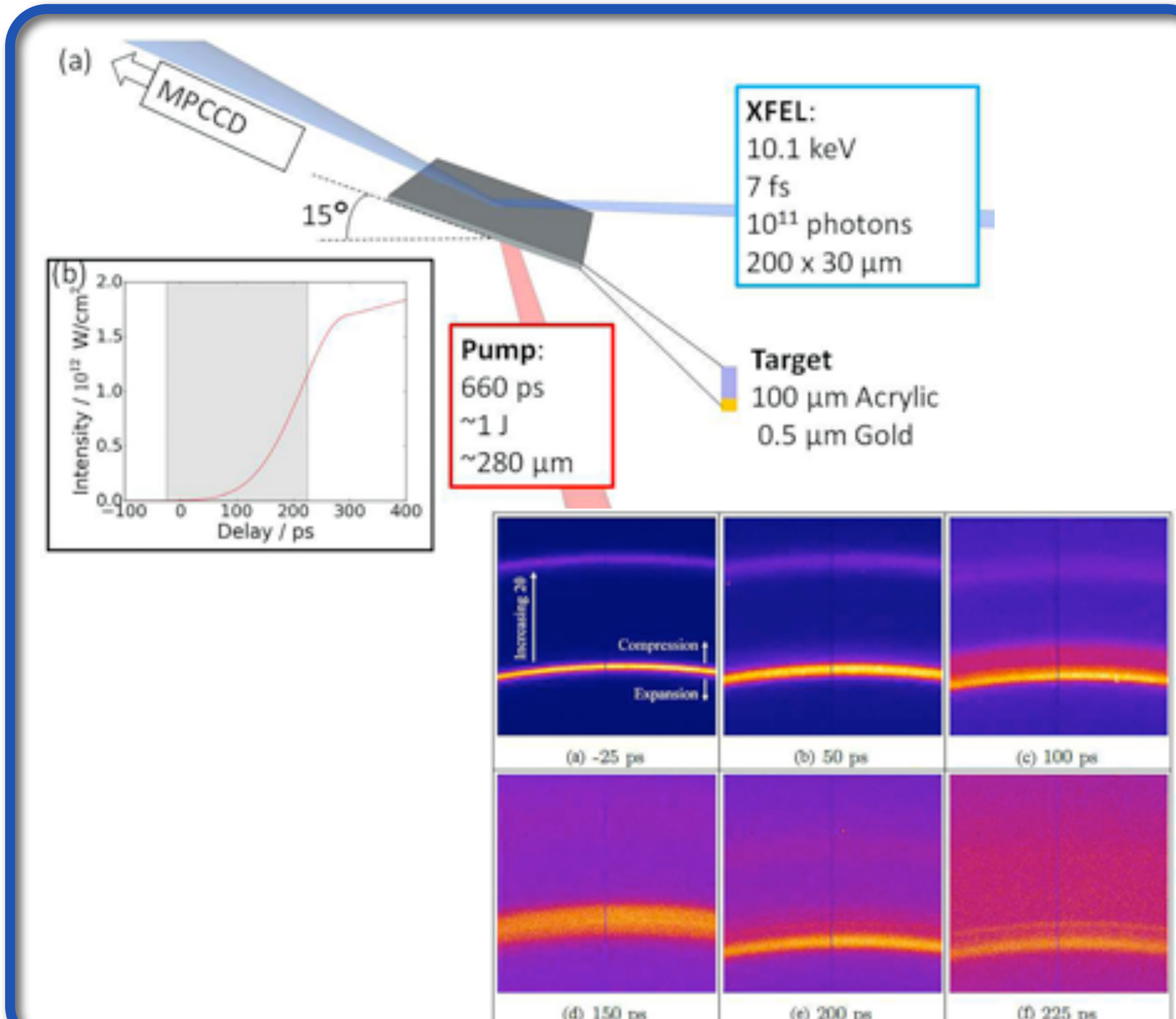
In collaboration with Harima Center for Photon Sciences, Osaka Univ. (Prof. R. Kodama)

Dynamic behavior of matter under high pressure is one of the hot topics in HEDS

B. Albertazzi, N. Ozaki et. al
Science Advances (2017)



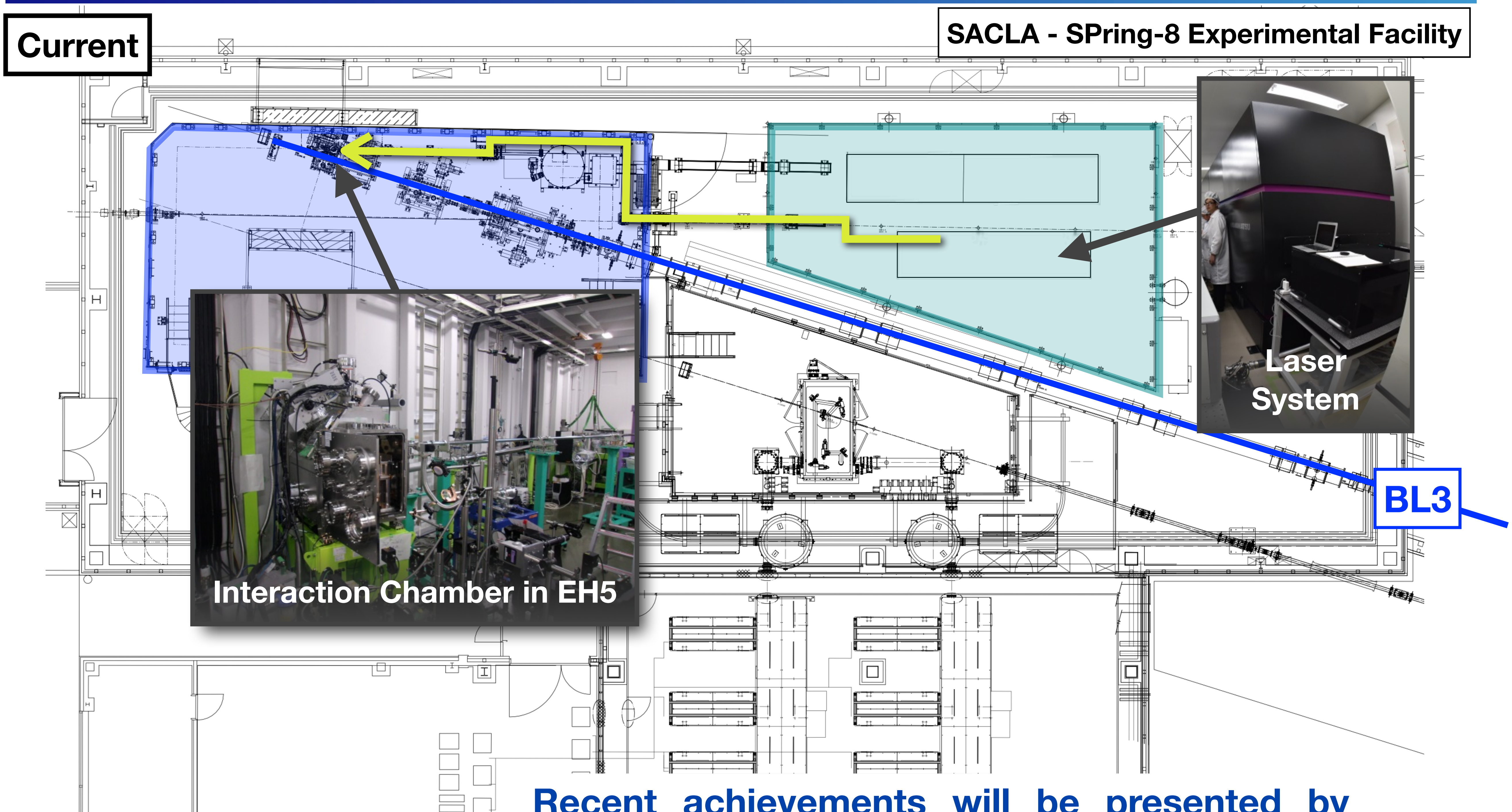
N. J. Hartley, N. Ozaki et. al
Applied Physics Letters (2017)



Above experiments were carried out with ~1 J, sub-ns laser.
(up to a few tens of GPa)

→ Long pulse laser (~10 J, ns) has been installed.

~10 J class, ns laser has been utilized for high pressure researches since 2015

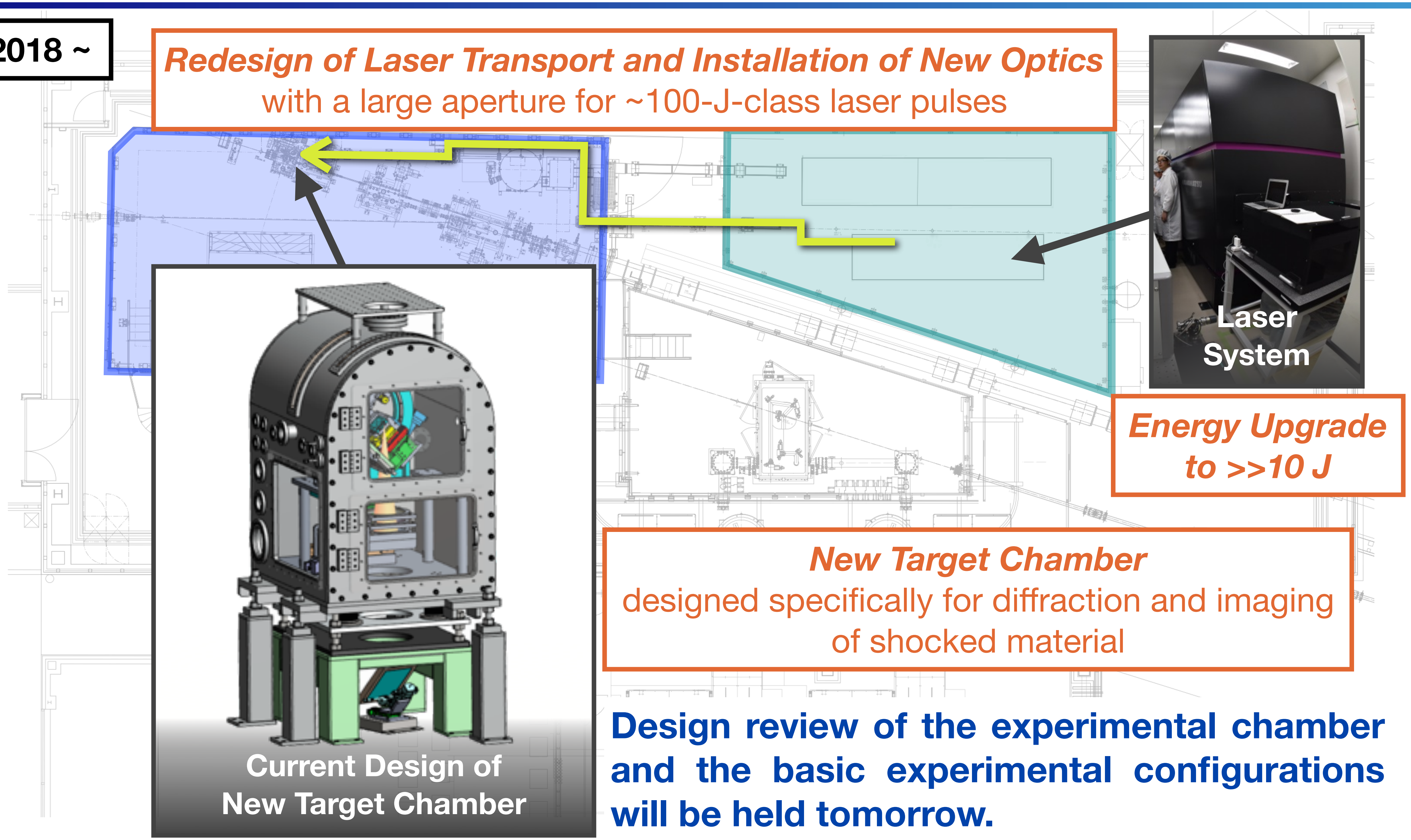


Recent achievements will be presented by Prof. N. Ozaki (Osaka U.) this afternoon.

New experimental system will be installed in summer 2018 for 100-J-class laser

2018 ~

Redesign of Laser Transport and Installation of New Optics
with a large aperture for ~100-J-class laser pulses



Energy Upgrade to >>10 J

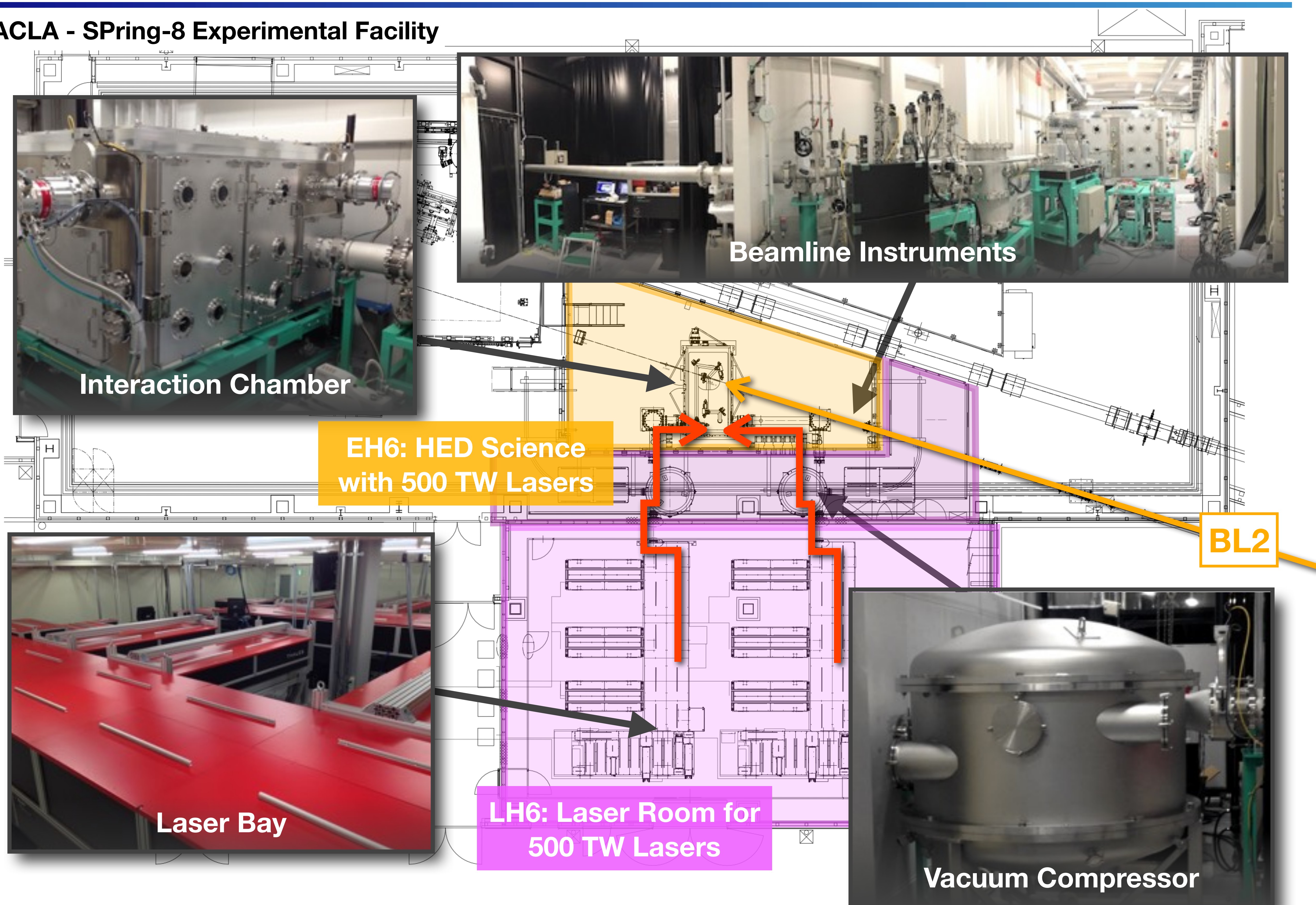
New Target Chamber
designed specifically for diffraction and imaging of shocked material

Design review of the experimental chamber and the basic experimental configurations will be held tomorrow.

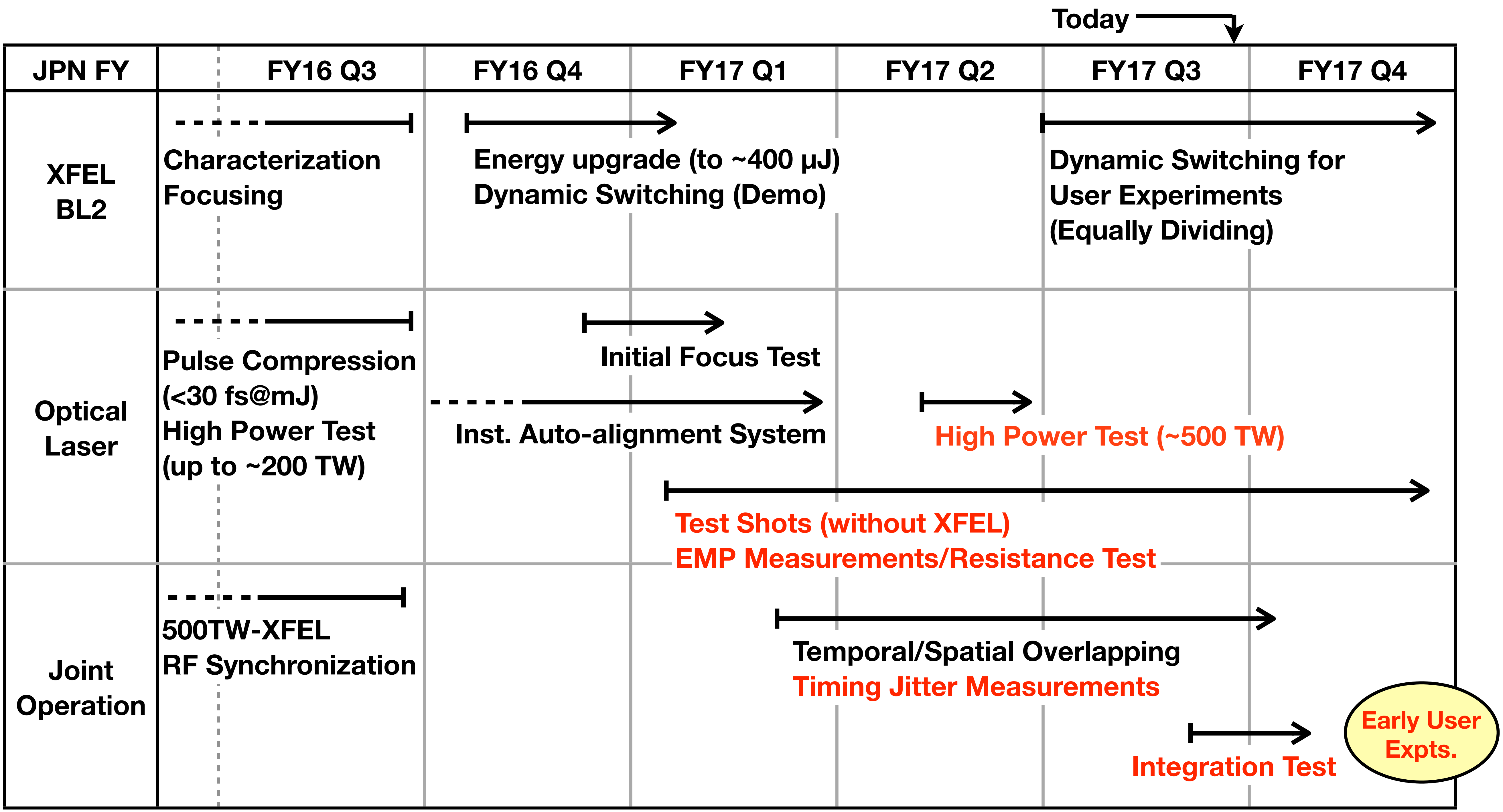
Inubushi and Togashi-san

Experimental Platform with High Intensity Lasers

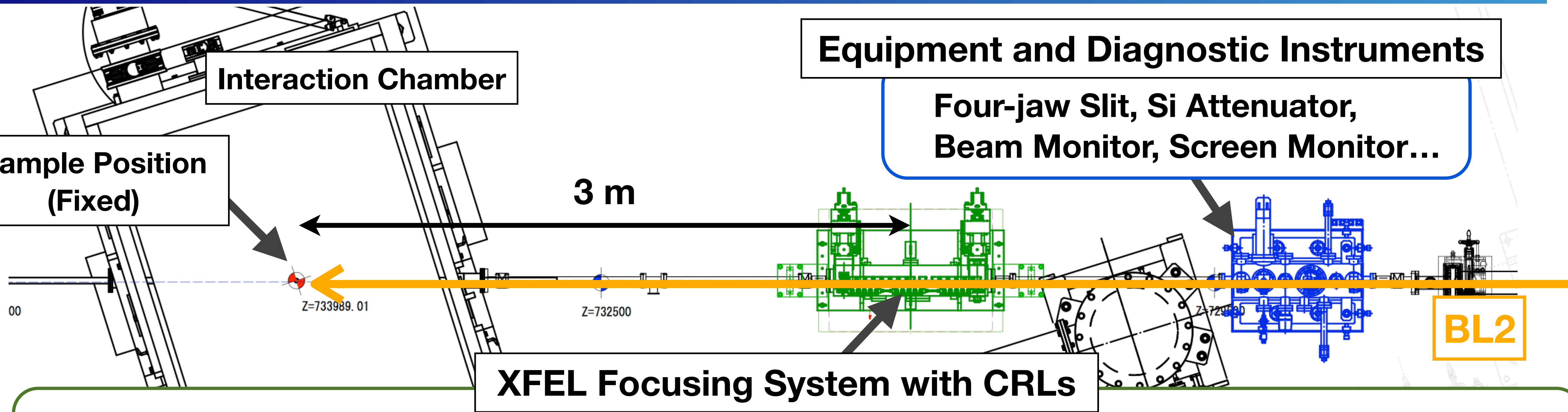
SACLA - SPring-8 Experimental Facility

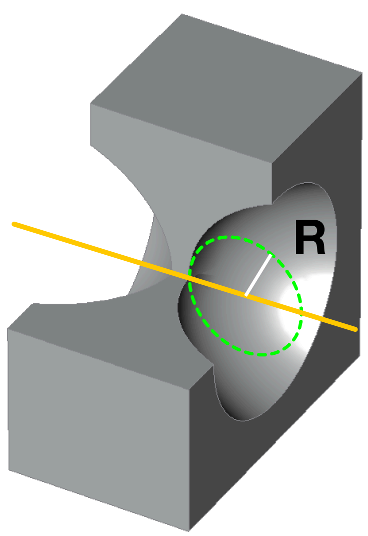


EH6 has been under commissioning for early user experiments starting in 2018

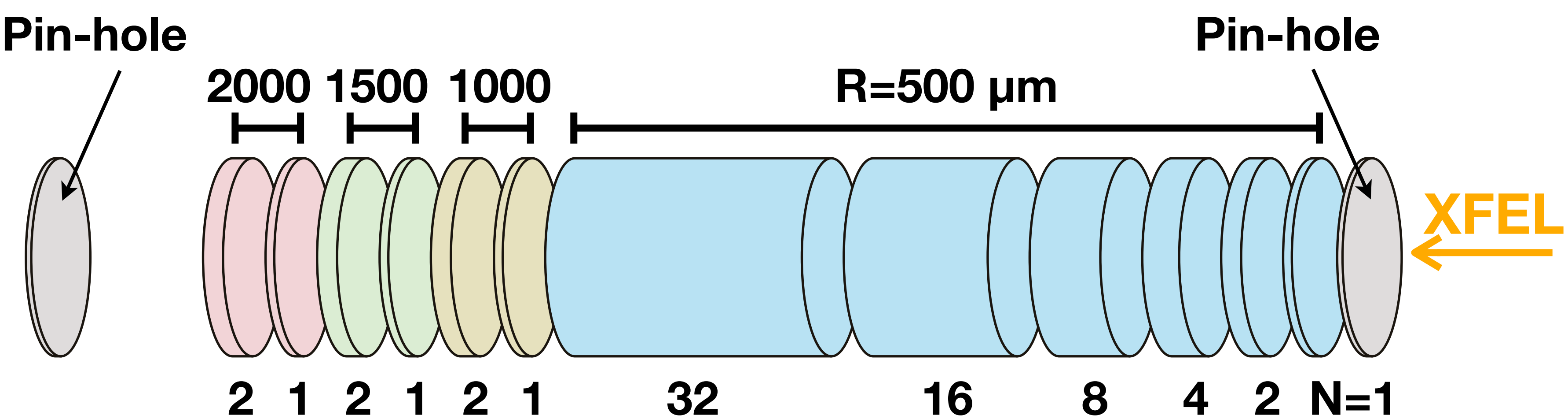


XFEL is focused with CRLs to avoid beam pointing offset so as to fix sample position





Compound Refractive Lens (CRL)



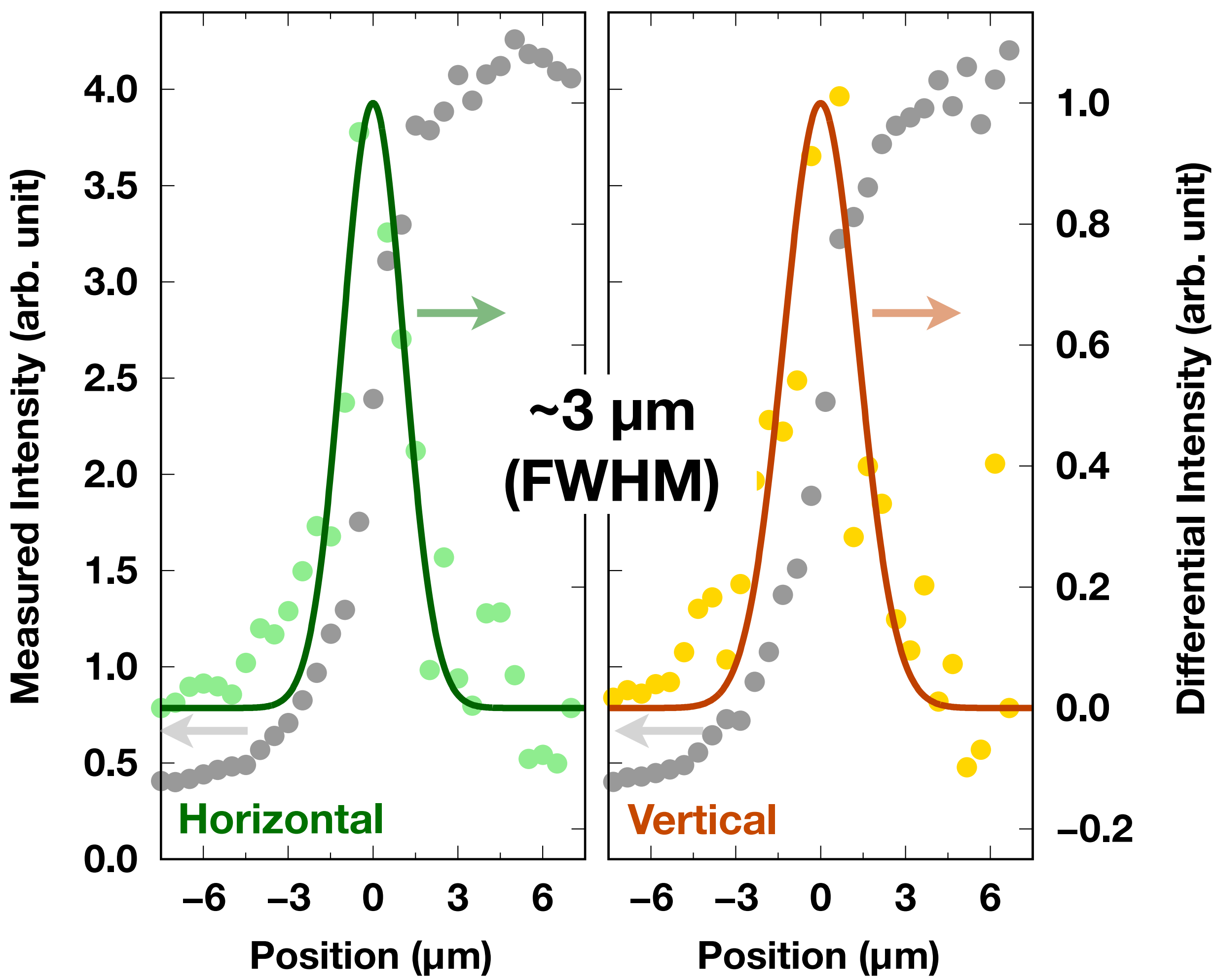
- CRLs are designed to focus 15 keV XFEL pulses down to a few µm.
- CRLs are “on-axis” optics and do not change the beam direction.
  → The position of sample/optical laser focusing can be maintained.

XFEL focusing down to a few μm has been demonstrated at the sample position

10 keV XFEL

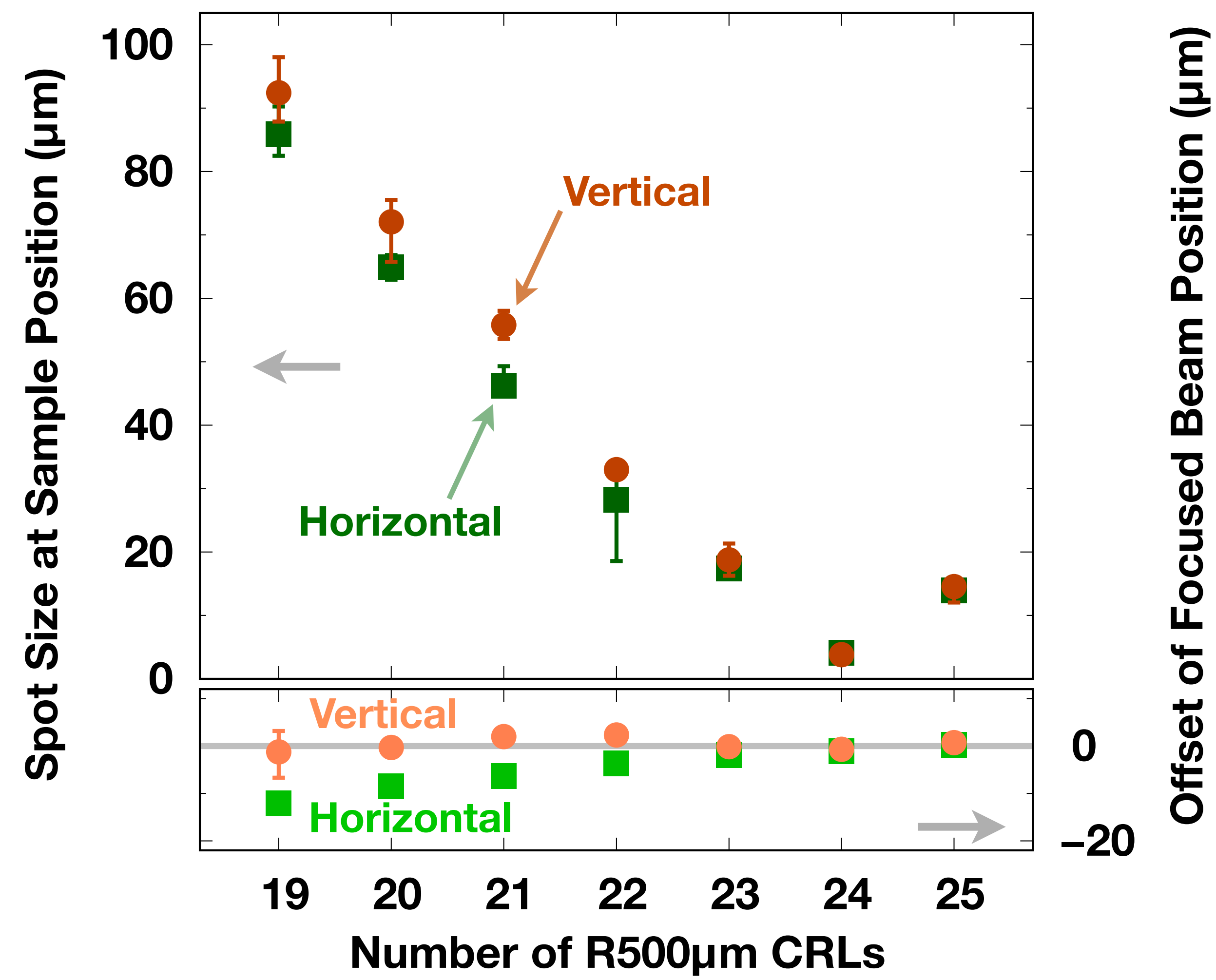
Focal Spot Profile

CRLs: 23xR500μm, 2xR1000μm, 0xR1500μm, 0xR2000μm



XFEL Spot Size and Beam Position

CRLs: Only R800μm, Various Number of Lenses



Focused intensity distributions were measured with the wire-scan technique at the sample position with a 200-μm-dia gold wire.

Commissioning of laser systems have been almost achieved to date

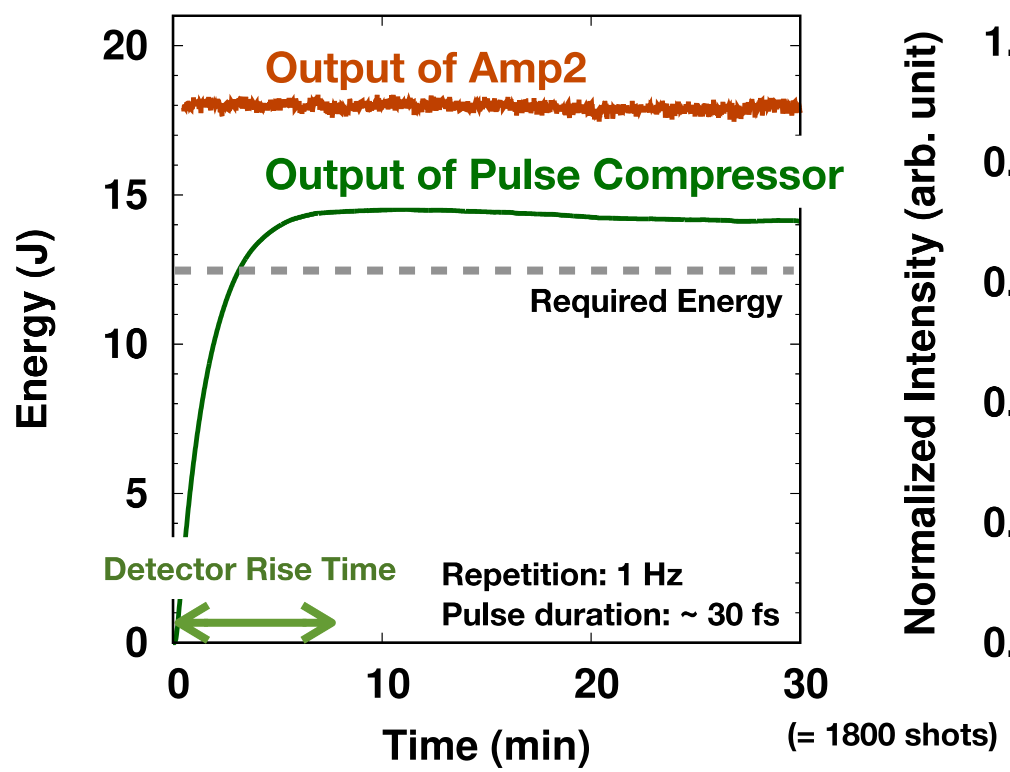
Achieved Specs:

- ☑ **Pulse Energy after Pulse Compression: >12.5 J**
- ☑ **Pulse Duration after Pulse Compression: ~25 fs**
- ☑ **Peak Power: ~500 TW**
- ☑ **Beam Size: 120-mm-dia. with Top Hat**
- ☑ **Central Wavelength: 800 nm (typ.)**
- ☑ **Pulse Contrast: 10^{-10}@–100 ps, 10^{-8}@–30 ps**
- ☑ **Repetition Rate: 1 Hz**
- ☑ **Relative Jitter between RF Clock and Laser: <20 fs (RMS)**
  - **Relative jitter between XFEL and laser is ~60 fs.**
  - **Long term (~24 hr) drift will be measured to confirm the influence of room temperature fluctuations in day and night.**

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

Tomizawa and Kon-san

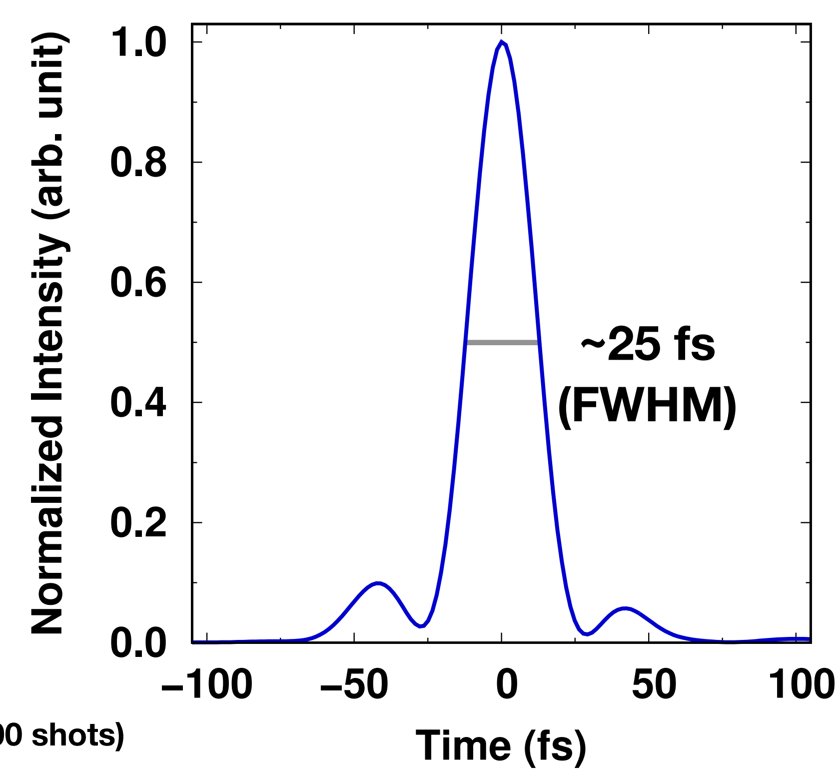
Pulse Energy



Design:
12.5 J after pulse compression

Energy transmission of ~75% has been demonstrated with sufficient energy to achieve ~500 TW.

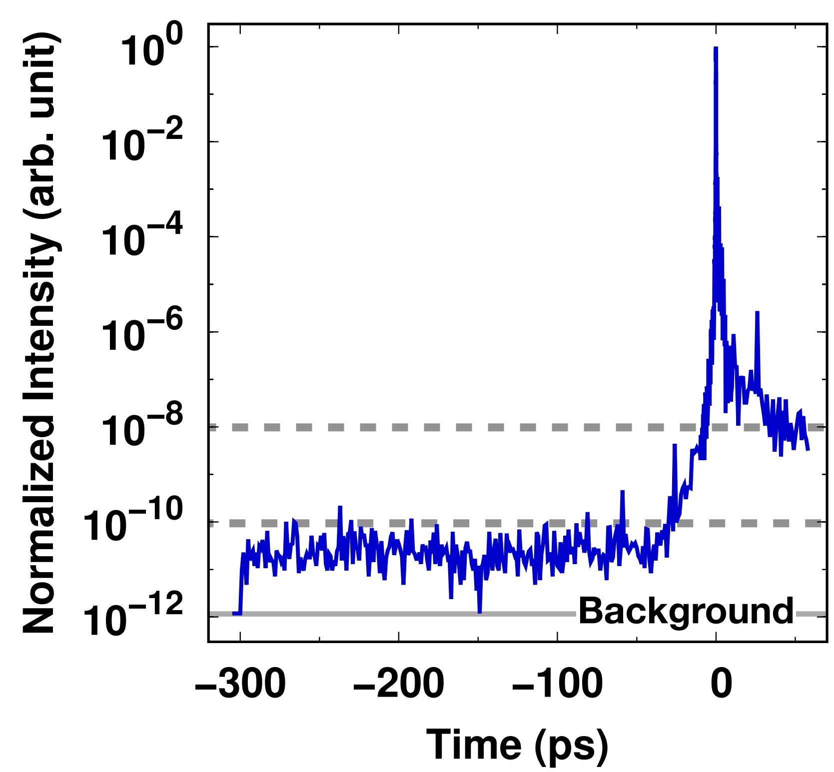
Pulse Duration



Design:
< 25 fs in FWHM

Pulse compression has been tested with attenuated beam after the full amplification.

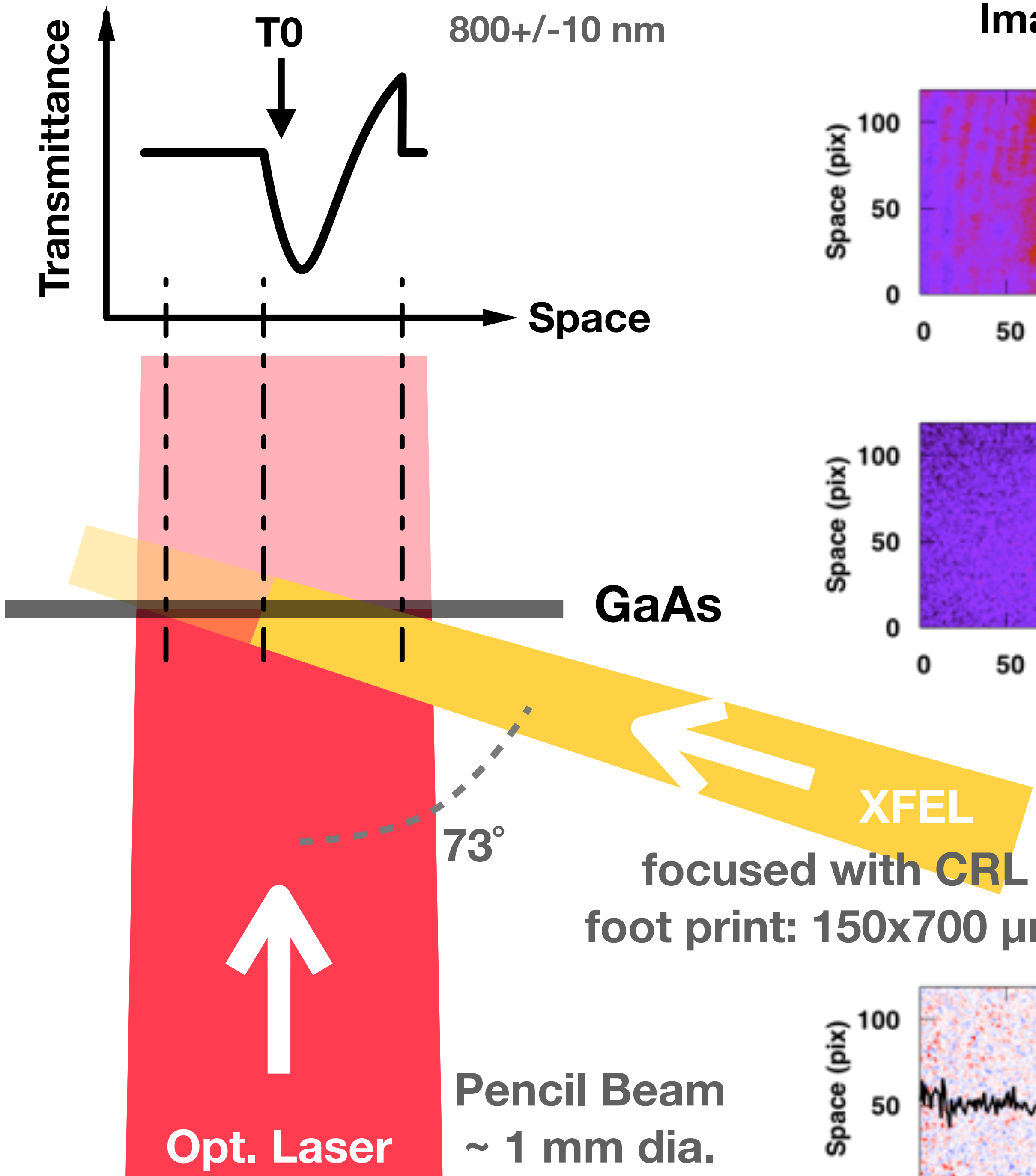
Pulse Contrast



Design:
10^{-10}@–100 ps, 10^{-8}@–30 ps

*The measurements were performed in single beam mode (ie. non-shared front-end)

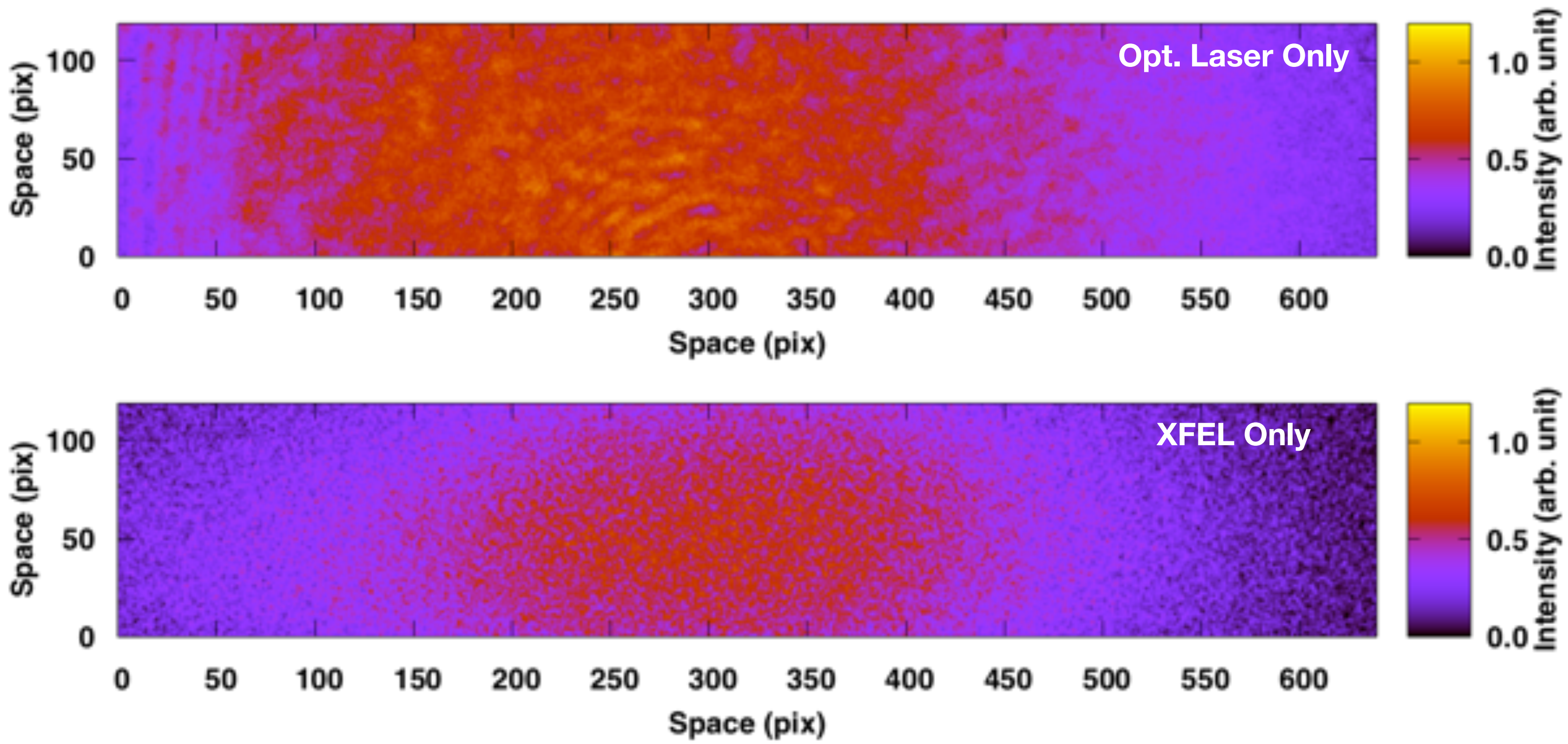
Timing jitter and drift has been measured between "XFEL and laser" at sample position



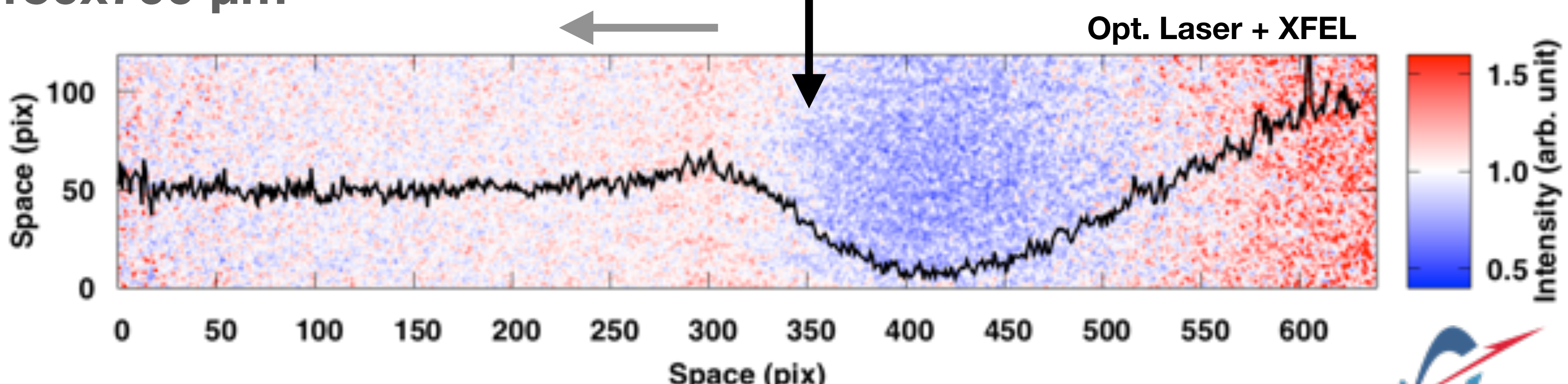
focused with CRL
foot print: 150x700 μm^2

Pencil Beam
~ 1 mm dia.

Images of Transmitted (Emitted) Lights from GaAs

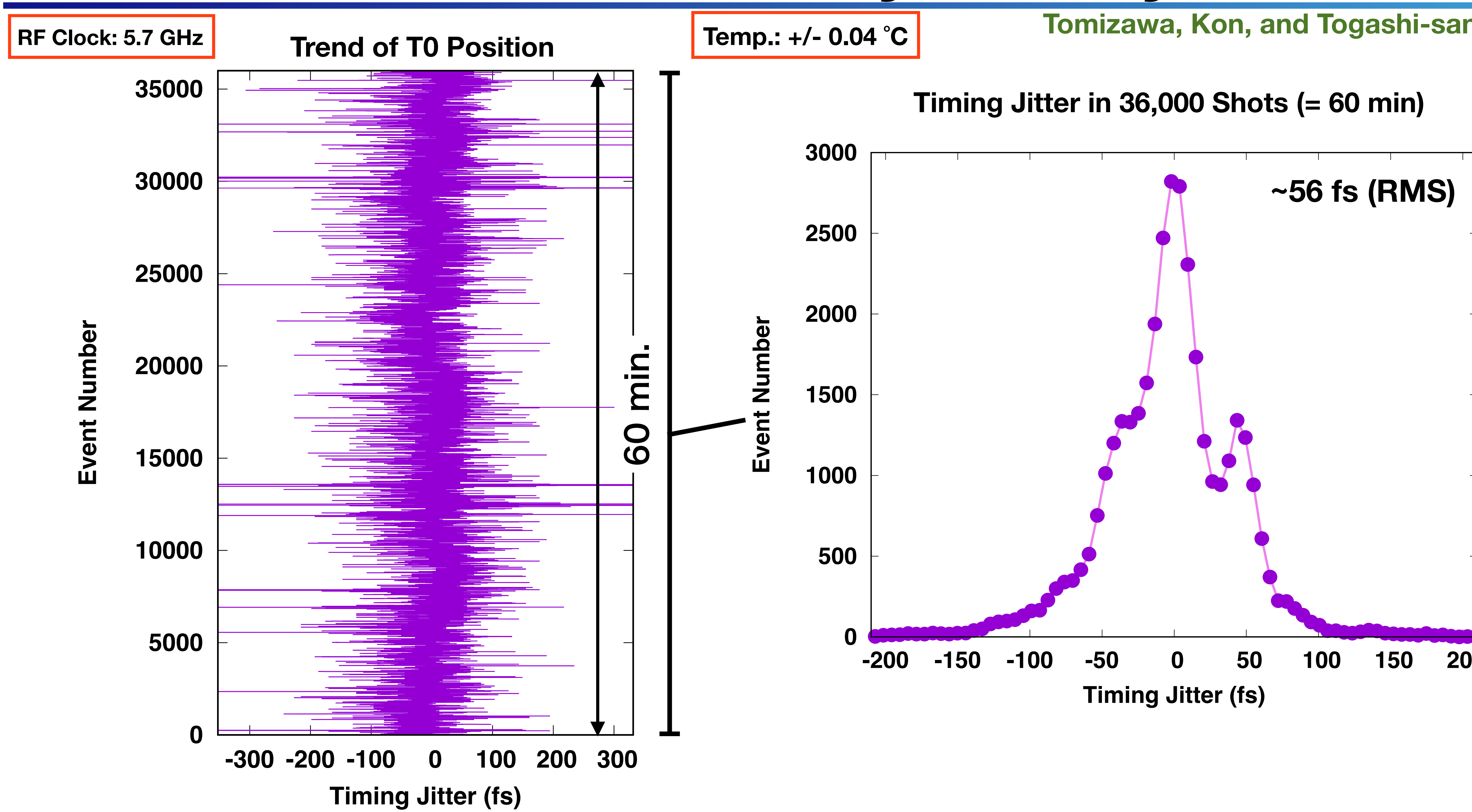


T0 defined as a pixel position where dI/dx gets the minimum value.



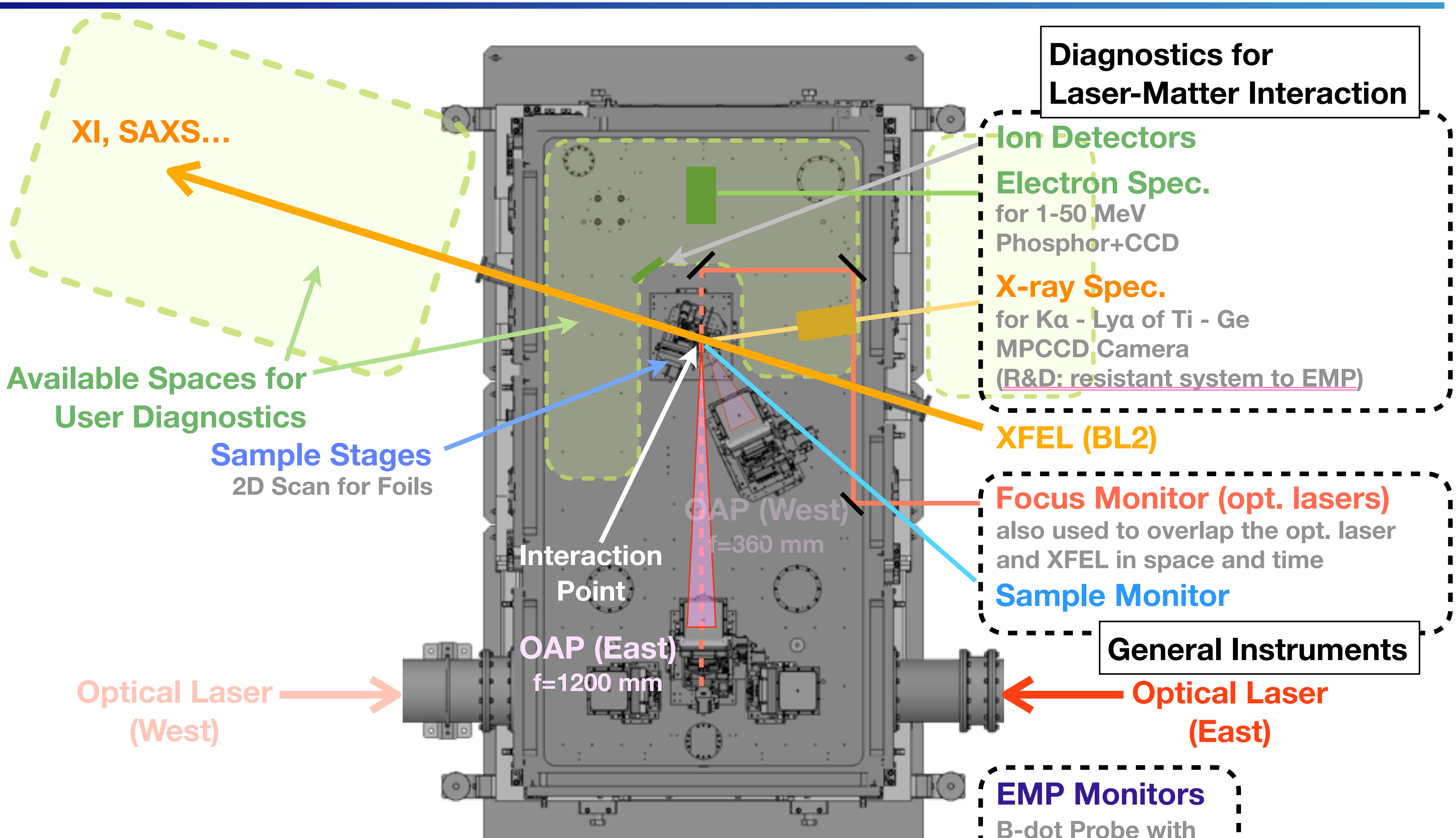
Improved timing jitter (~60 fs) has been observed because of new synchro system

Tomizawa, Kon, and Togashi-san



→ **Long term drift will be measured to understand the influence of room temperature fluctuations in day and night.**

Basic diagnostics are under preparation to characterize the laser-matter interactions



Top View of 1st Floor in Interaction Chamber

Plasma expansion caused by laser irradiation has been probed with XFEL

Preliminary Demonstration

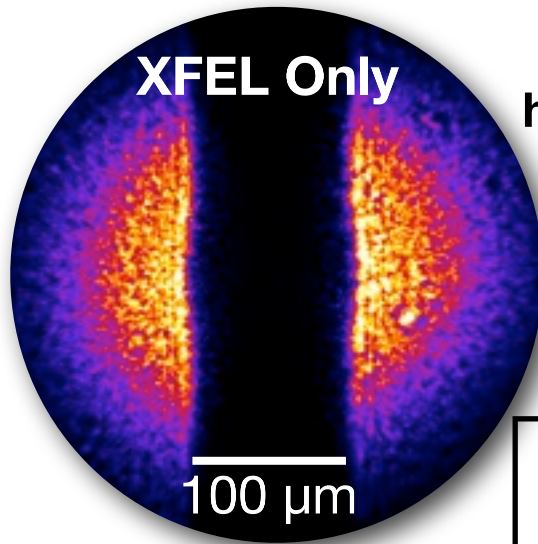
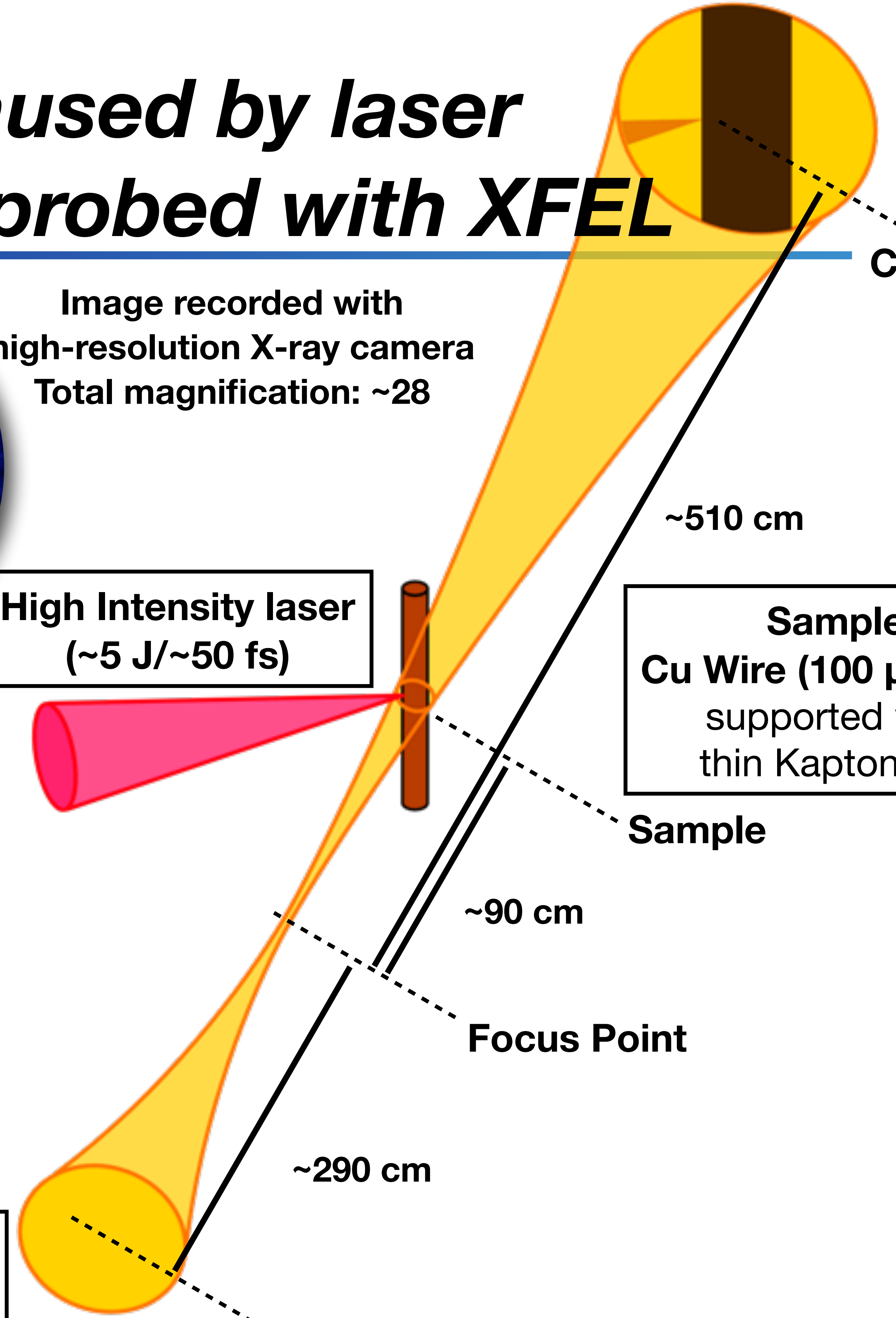


Image recorded with high-resolution X-ray camera
Total magnification: ~28

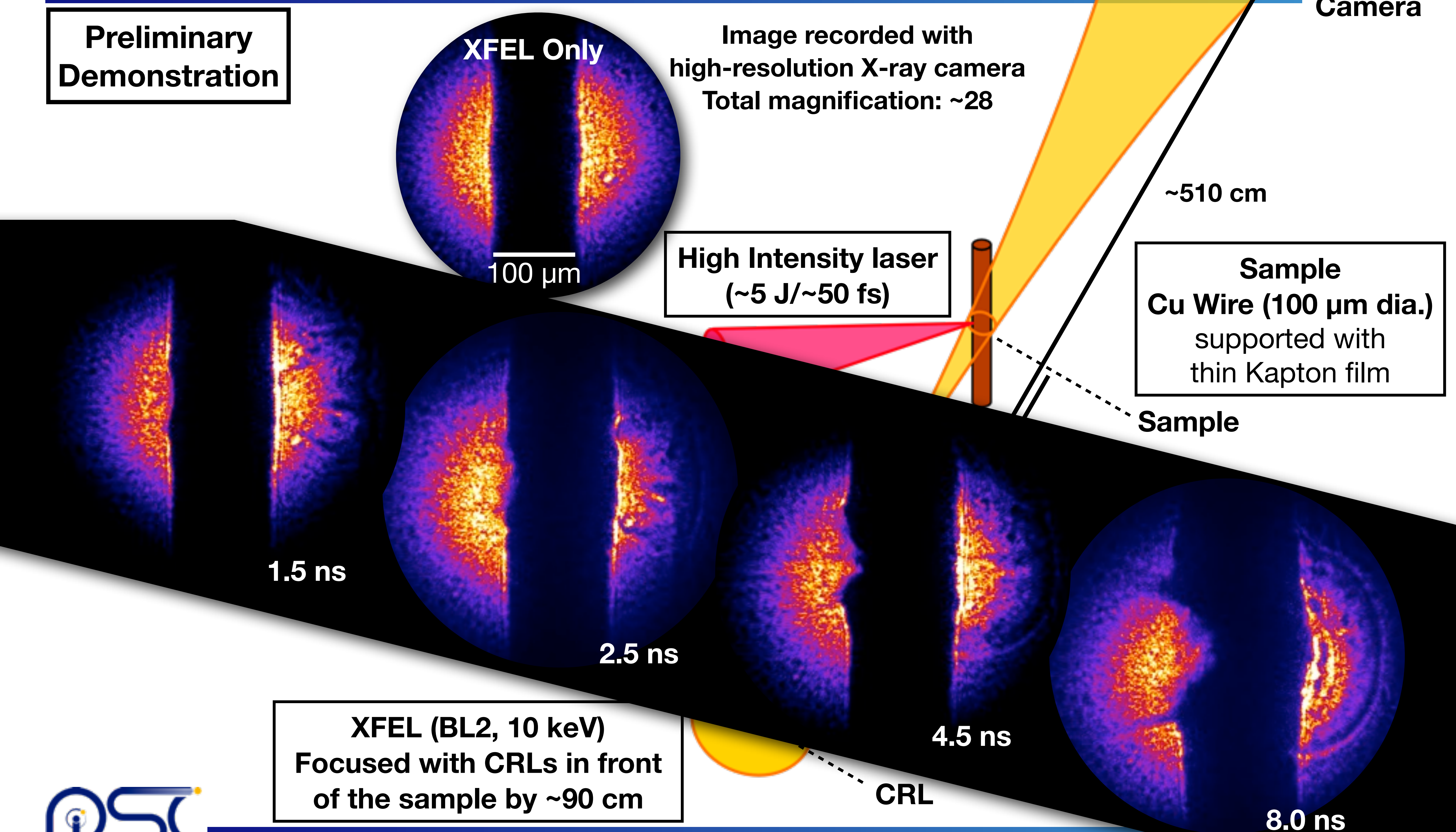


High Intensity laser
(~5 J/~50 fs)

Sample
Cu Wire (100 μm dia.)
supported with
thin Kapton film

XFEL (BL2, 10 keV)
Focused with CRLs in front of the sample by ~90 cm

Plasma expansion caused by laser irradiation has been probed with XFEL



Next Steps for Full Operation of HEDS Stations

- **Timing Tools**
  - Development of reliable time delay system and “on-shot” arrival timing monitor
- **Optical Laser Beam Quality**
  - Wavefront correction for focusing improvement and for robust operation with high power avoiding damage on optics
- **EMP Resistant Instruments**
  - Development of resistant components/instruments to harsh environment including strong electromagnetic pulses (EMP)
- **Automated Technologies**
  - Development of automated technologies for stable laser operation, high-rep rate sample delivery, and their alignment system
- **Second Short-pulse Beam**
  - Commissioning of 2nd beam of high-intense laser with a short focal length

Summary

- SACLA has **two types of high-power optical lasers** (long pulse and short pulse) synchronized with the XFEL for HEDS.
- The experimental platform in **EH5 will be upgraded in summer 2018** to accept increased pulse energies of the long pulse laser and enable advanced experiments.
- The experimental platform in **EH6** for the combinative use of the high intensity laser and the XFEL is under commissioning. **Early user experiments are planned to start in 2018A**.
- For more stable and robust operation of the experimental platforms for HEDS, further developments will be carried out.

Any inputs are very much appreciated!

Acknowledgements:
Profs. N. Ozaki, H. Habara, and R. Kodama (Osaka University)