

# XFEL beamlines

Kensuke Tono (SACLA)

# Contents

- Beamline updates
- Basic policies for the parallel operation of 3 beamlines
- Summary

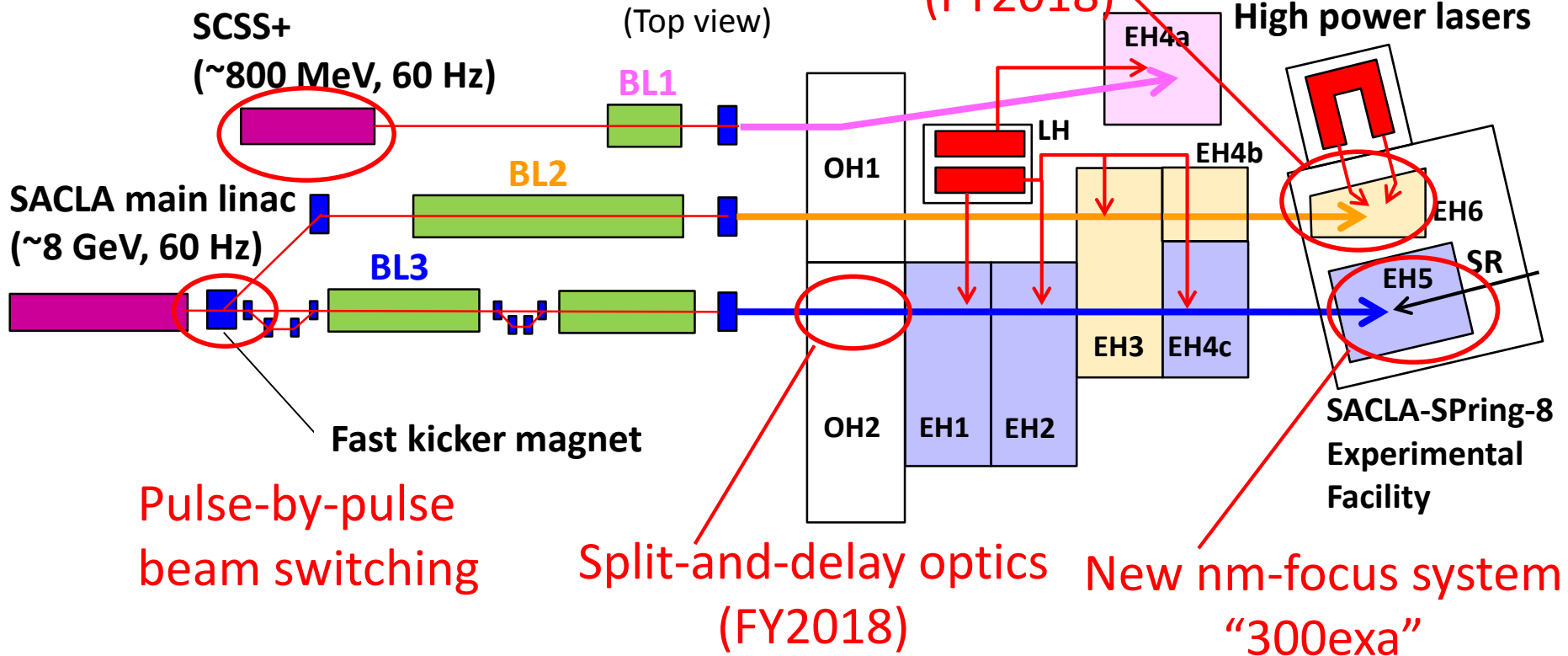
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# Three beamlines are operating.

SXFEL (BL1) => Owada-san

HEDS station => Yabuuchi-san  
(FY2018)



- BL1: Soft X-ray FEL (40 - 150 eV)
- BL2: Hard X-ray FEL (4 - 15 keV)
- BL3: Hard X-ray FEL (4 - 15 keV)

# Current XFEL Properties (standard operation mode)

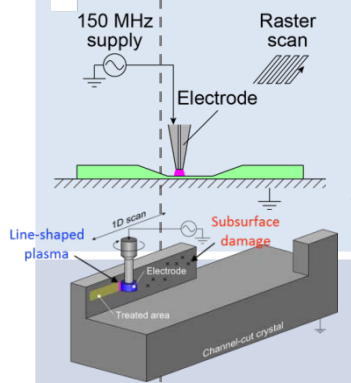
<http://xfel.riken.jp/users/index.html>

	BL2	BL3
Photon energy (Pulse energy)	4—15 keV (~500 $\mu$ J@10 keV)	4—15 keV (~600 $\mu$ J @ 10 keV) (~200 $\mu$ J @ 15 keV)
Pulse duration	<10 fs	<10 fs
Peak power	>50 GW @ 10 keV	>60 GW @ 10 keV
Rep. rate	30 Hz (Max. 60 Hz)	30 Hz (Max. 60 Hz)
Band width	~ $5 \times 10^{-3}$ (pink) ~ $1 \times 10^{-4}$ (mono)	~ $5 \times 10^{-3}$ (pink) ~ $1 \times 10^{-4}$ (mono)

# New BL components for time-resolved studies (BL3)

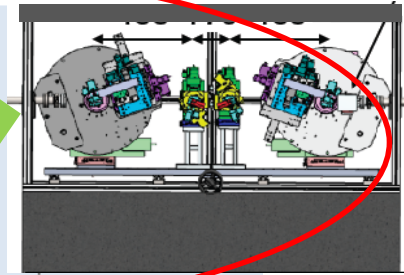
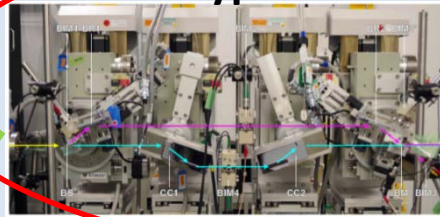
Crystal machining

User operation



SDO

Prototype SDO

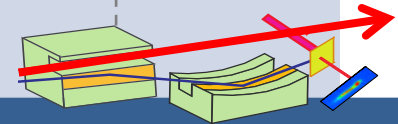
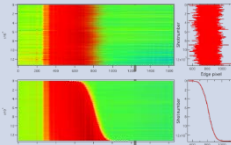
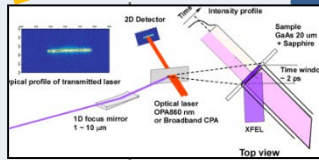


Beam splitting

Collaboration with PSI

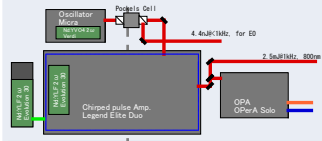


Timing tool



Standard BL component

Timing Synchronization



Prototype

Fundamental technologies

FY2011

2012

2013

2014

2015

2016

2017

Construction

Development phase

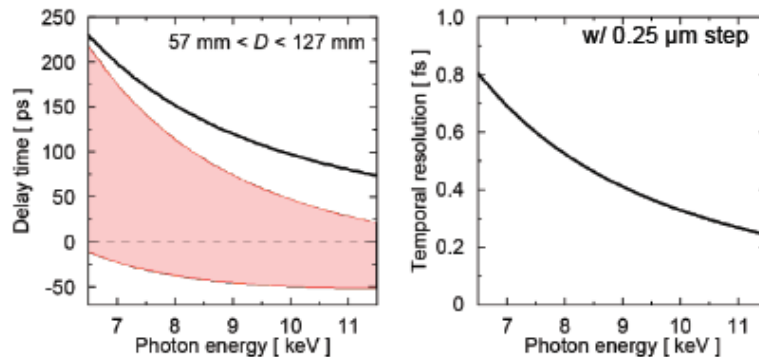
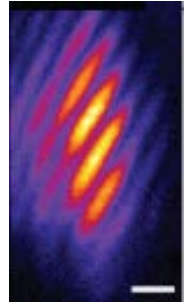
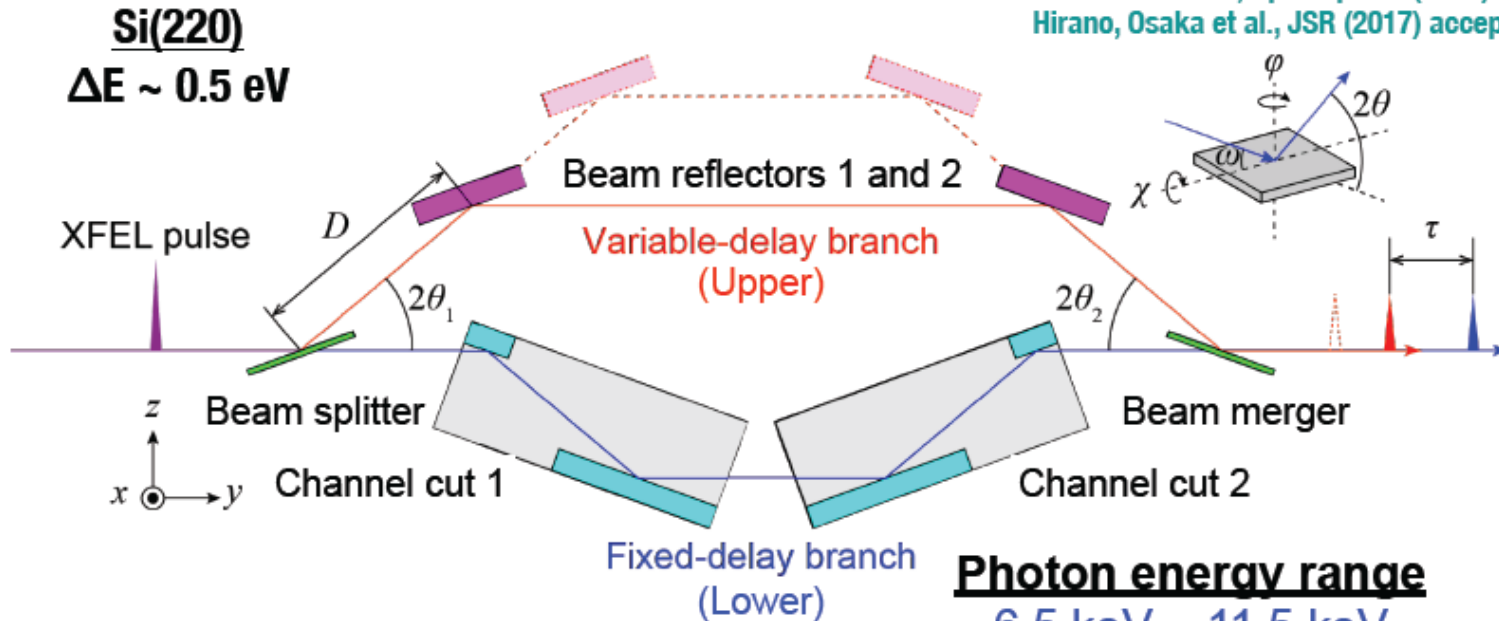
Present phase

SACLA Users Meeting

6

# Split and delay optics

Osaka et al., Opt. Express (2016)  
Hirano, Osaka et al., JSR (2017) accepted.



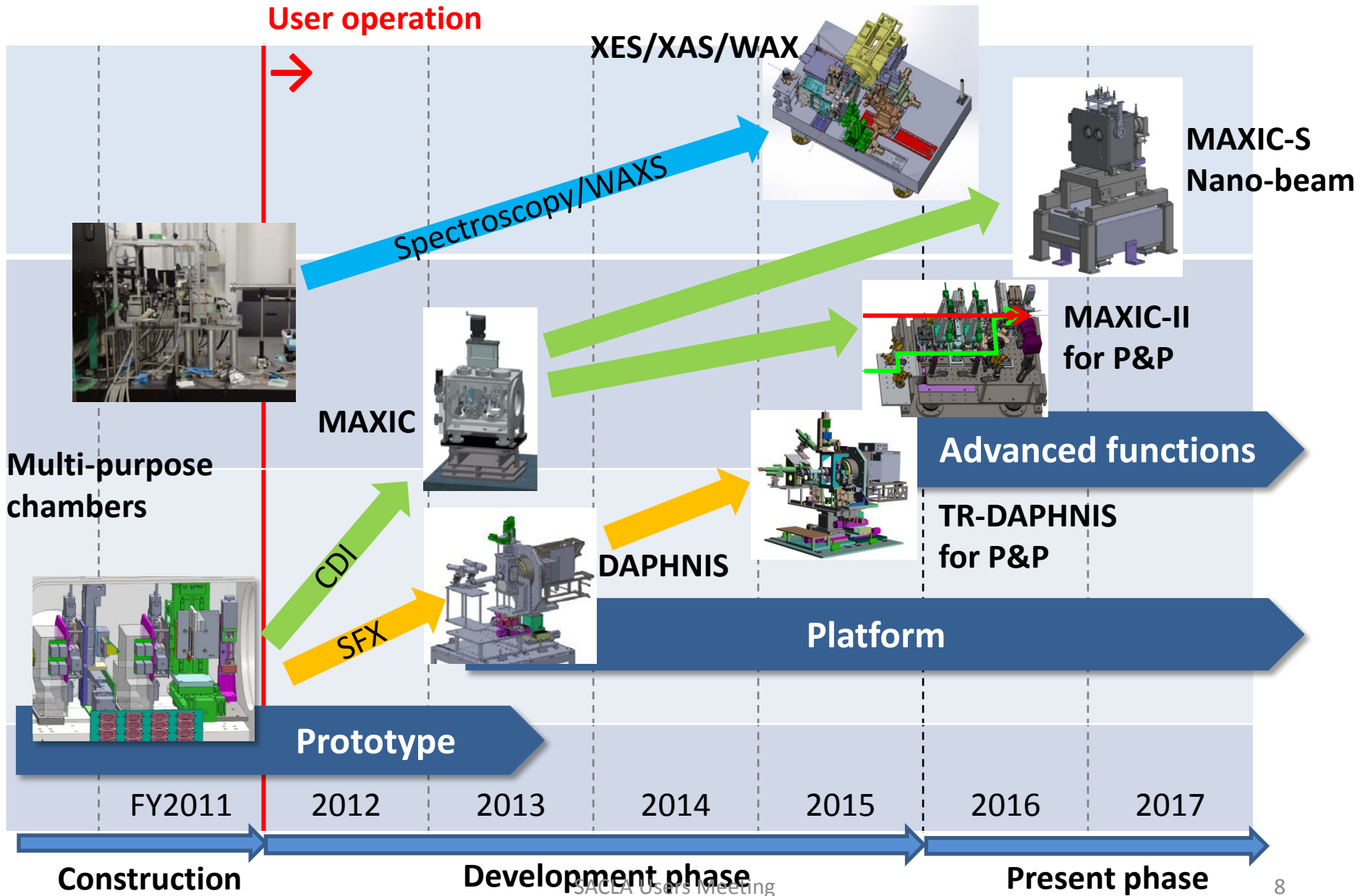
**Photon energy range**  
6.5 keV ~ 11.5 keV

**Delay time range @10 keV**  
-50 ~ +47 ps w/ <1 fs step  
(up to 220 ps @6.5 keV)

**Intensity @10 keV**  
0.15–0.2  $\mu\text{J}/\text{pulse}$   
(average)

- Prototype has been applied to user experiments
- Installed into BL3 as a standard component (FY2018)

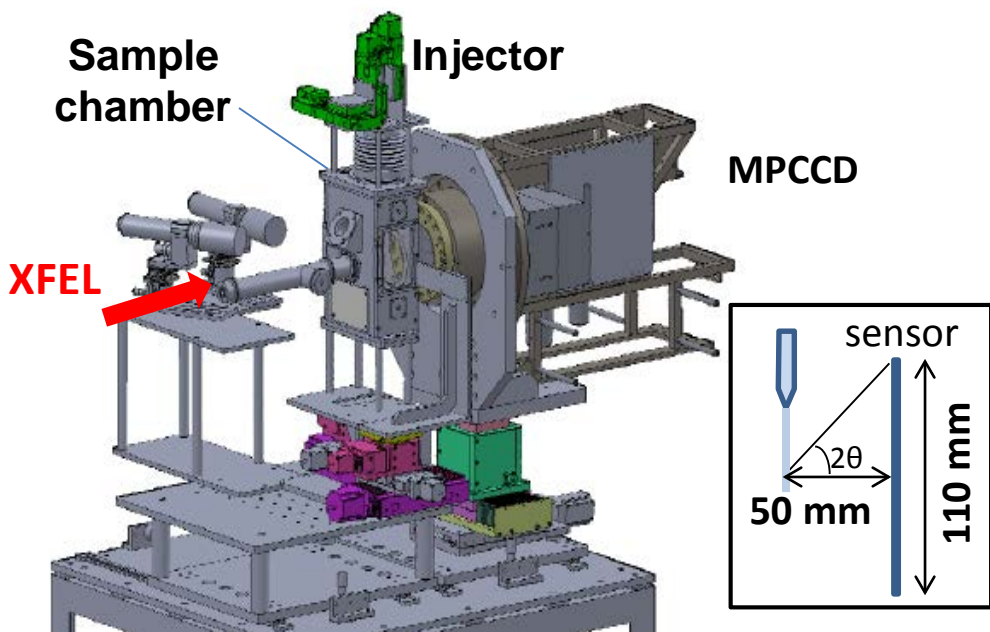
# Experimental platforms





# Diverse application platform for hard X-ray diffraction in SACLA (DAPHNIS)

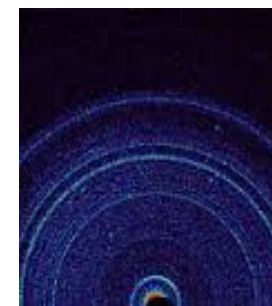
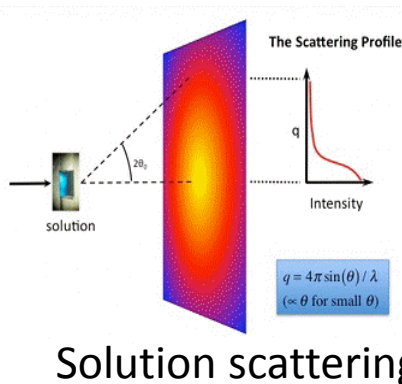
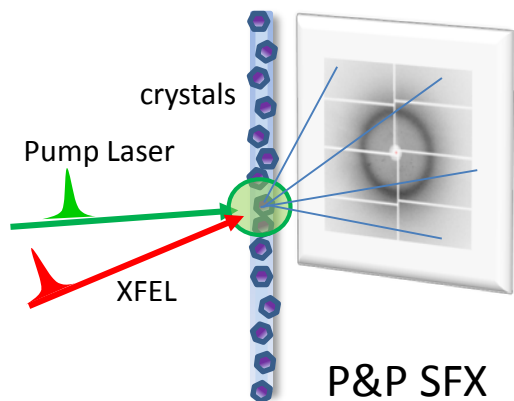
Tono et al., *J. Synchrotron Rad.* (2015)



DAPHNIS consists of compact & exchangeable components

- Operated under atmospheric pressure (He atmosphere)
- Easy to handle (Users can do measurement by themselves.)
- Flexible system adaptable to various types of injectors.

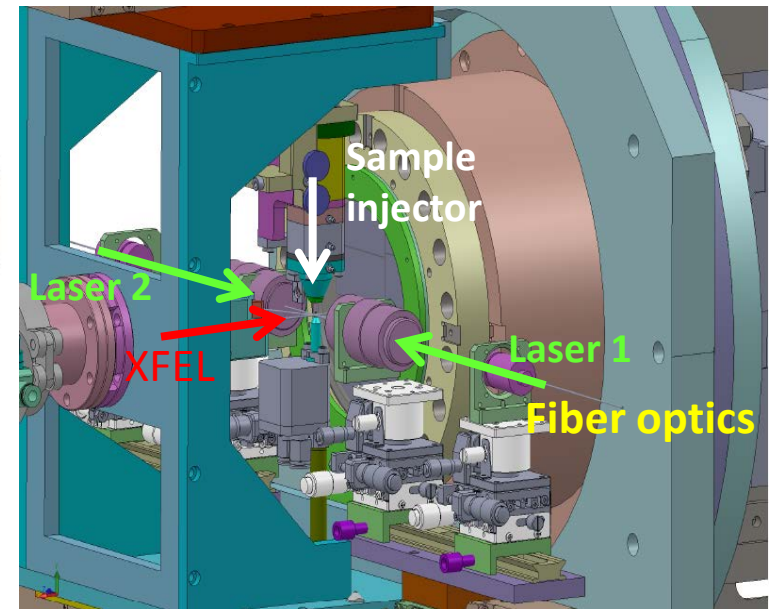
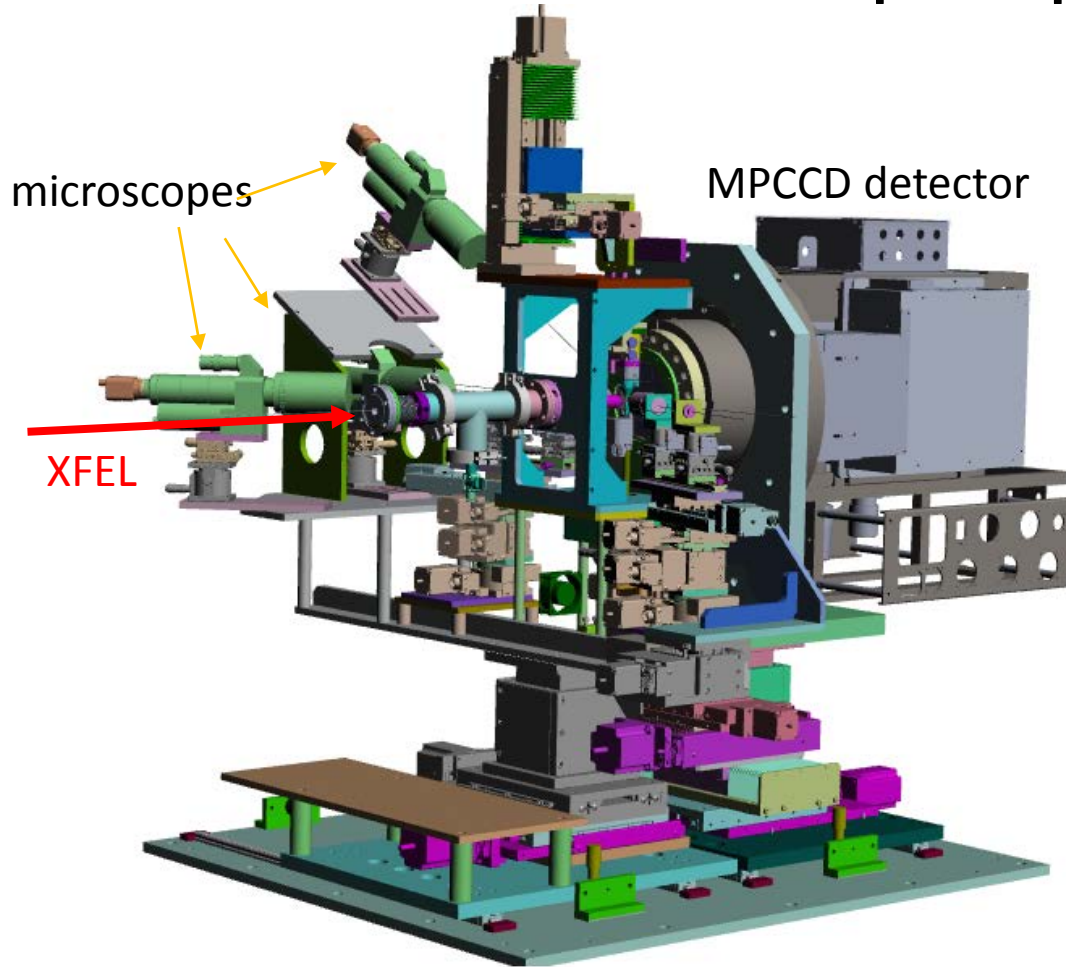
Applicable not only to SFX with protein crystals, but also to diffraction/scattering experiments for solution/solid samples with P&P capability



Powder diffraction

# Nanosecond pump-probe SFX

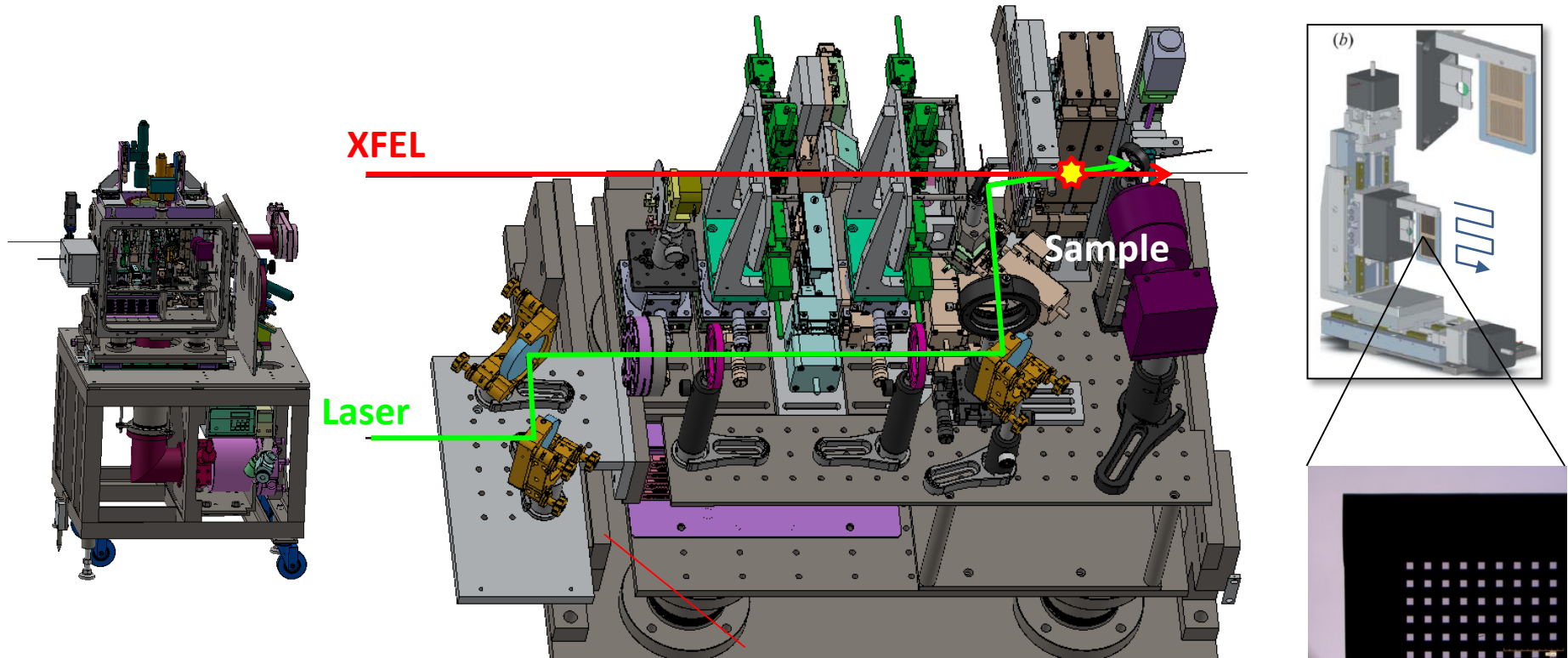
Kubo, Nango, Tono, et al. JSR (2017)



- P&P measurement using nanosecond lasers.
- Two-beam pumping in a nearly counter-propagating geometry.
- Liquid-jet, droplet, and viscous-carrier injectors are available.

# MAXIC-II for pump-probe study

MAXIC (Multiple Application X-ray Imaging Chamber) was upgraded to facilitate experimental operation in CDI.



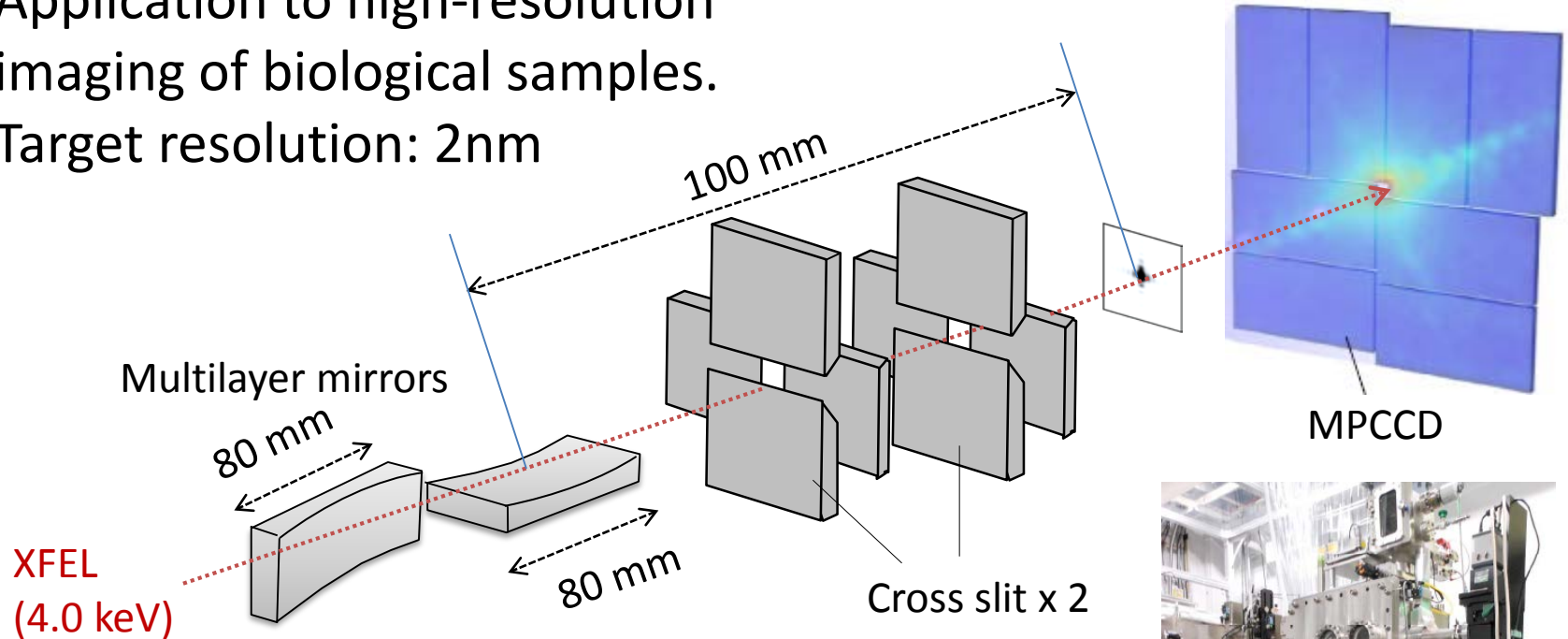
- Pump-probe capability.
  - Quasi coaxial incidence of laser & XFEL.
- Fast scanning of fixed targets.
- Long camera distance ( $\sim 10$  m) possible at BL2 EH3&4b

# MAXIC-S for nano-beam CDI



Yumoto, Koyama, Ohashi (JASRI)  
Kimura, Nishino (Hokkaido U.) et al.

- Application to high-resolution imaging of biological samples.
- Target resolution: 2nm



XFEL  
(4.0 keV)

Multilayer mirrors

80 mm

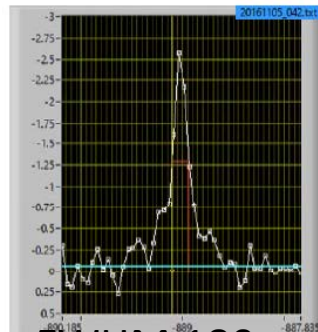
80 mm

100 mm

Cross slit x 2

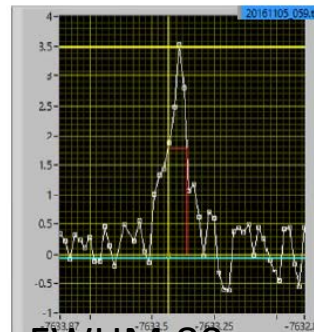
MPCCD

Horizontal



FWHM 180 nm

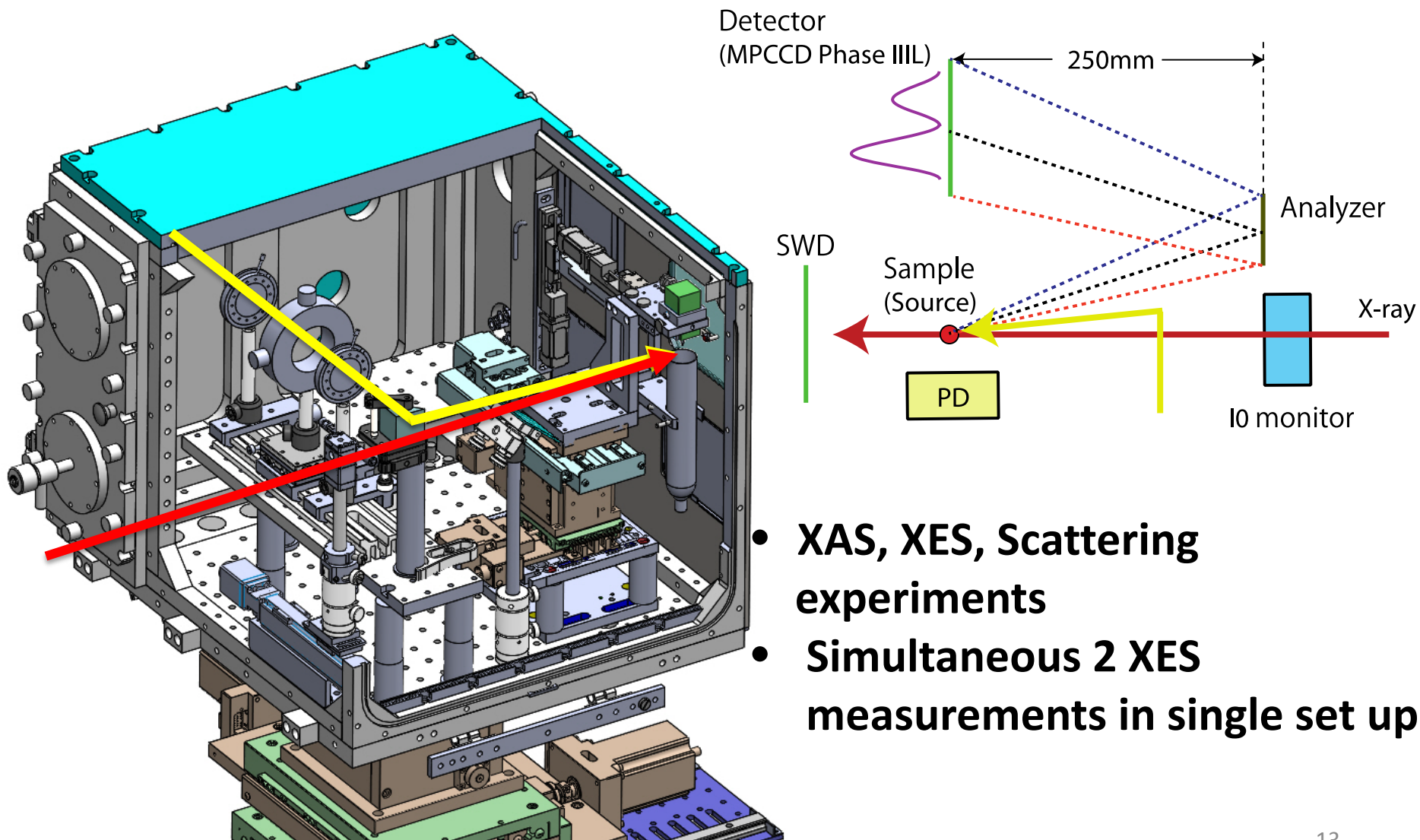
Vertical



FWHM 80 nm



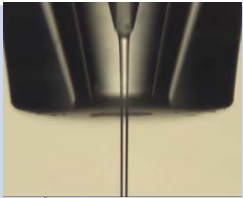
# Platform for ultrafast experiment (spectroscopy/scattering)



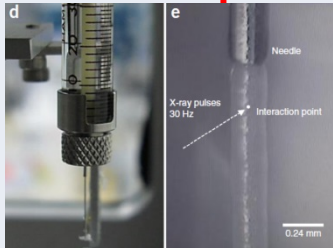
# Sample injectors

User operation →

Liquid jet

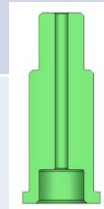
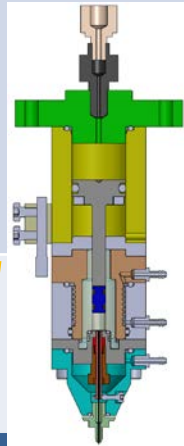


Viscous carrier

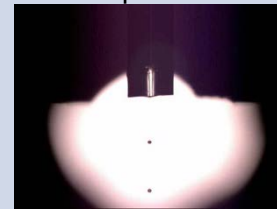


GVDN

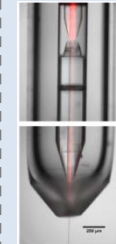
Syringe pump



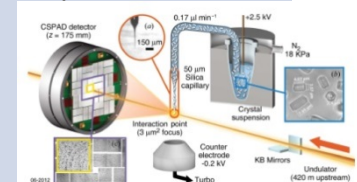
Droplet



Mix-and-jet



Electrospun



Advanced applications

Standardized

Prototype

Calvey et al, Str. Dyn. (2016)  
 Stagno et al., Nature (2017)  
 Sierra et al., Acta Cryst. D (2012).

FY2011

2012

2013

2014

2015

2016

2017

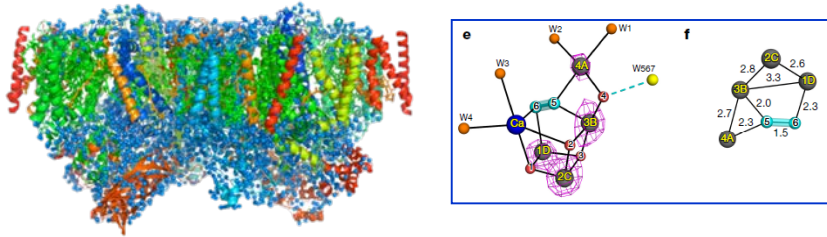
Construction

Development phase

Present phase

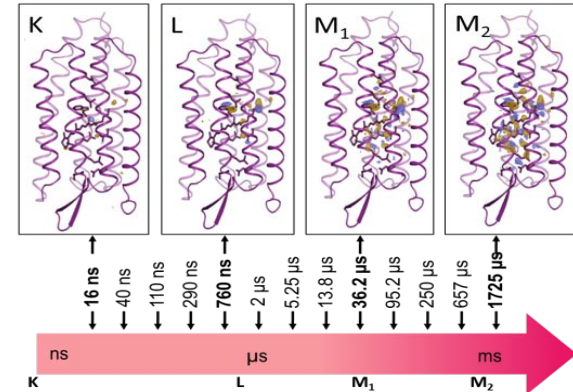
# Results from the platforms

## Intermediate states in photo-cycle of PSII



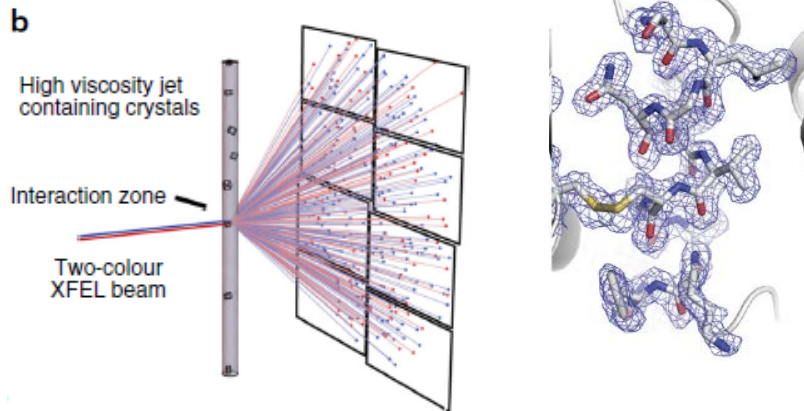
Suga, Shen *et al.*, *Nature* 543, 131 (2017).

## Ion transport mechanisms of photo-activated protein



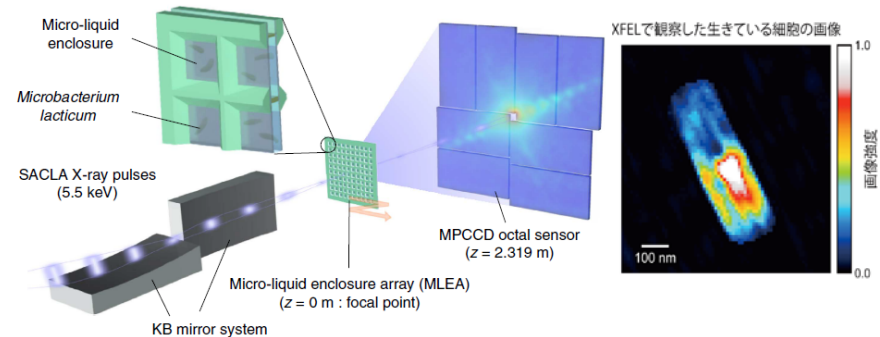
Nango, Iwata *et al.*, *Science* 354, 1552 (2016).

## MAD phasing with 2-color XFEL



Gorel, Barends, Schlichting *et al.*, *Nat. Commun.* 8, 1170 (2017).

## Live-cell imaging



Kimura, Nishino *et al.*, *Nat. Commun.* 5 3052 (2013).

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# BL1 (SXFEL)

- Users are encouraged to use their own instruments to perform experiments by themselves.
- Generally one user group in a week.
- Relatively long beamtime (e.g., 7 shifts) is allocated to each experiment.
  - Preparing high-vacuum instruments needs long time.

# BL2 (XFEL)

- Biology-oriented applications (PX, CDI, etc)
- Standard experimental systems (DAPHNIS, MAXIC, etc.) are stationed at EH for relatively long term.
- These systems are commonly used by multiple user groups.
- Feasibility-check beamtime from 2017B.
- HEDS station at EH6 from 2018A.

# BL3 (XFEL)

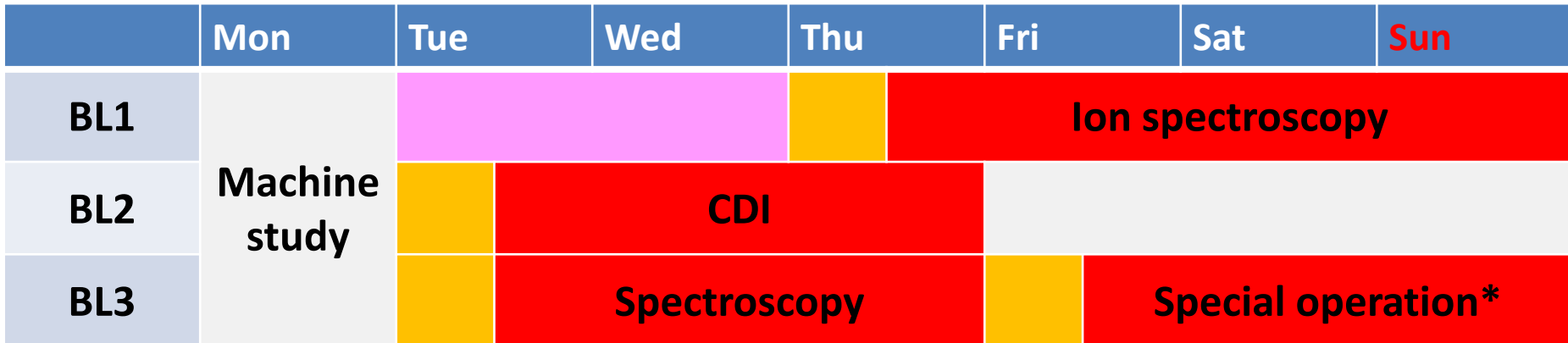
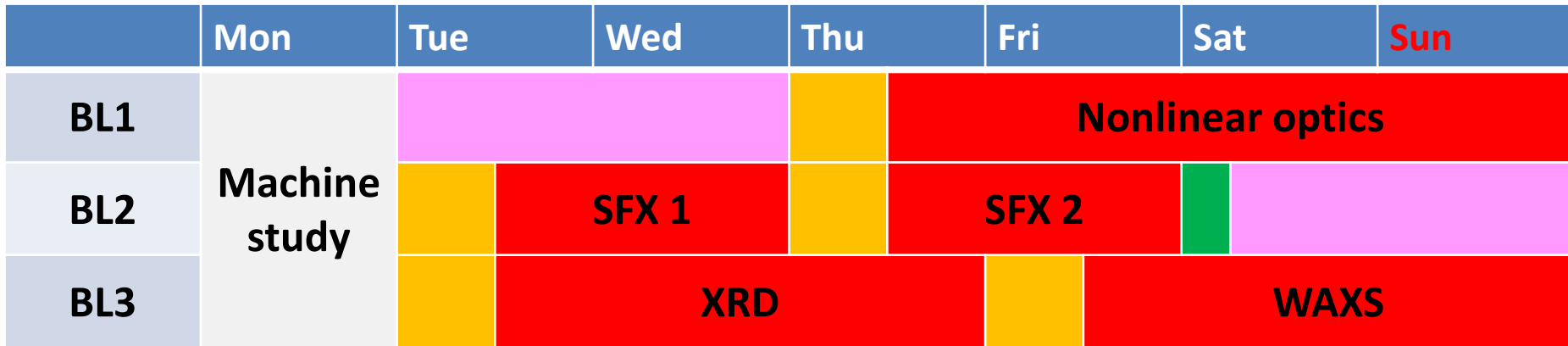
- Large flexibility for a wide variety of experiments.
- Especially ultrafast measurement with the fs laser and timing tool.
- Special operation modes
  - Double XFEL pulses with different colors, time delay between them
- Advanced optical and diagnostic tools
  - Nanometer focusing system (300exa) at EH5
  - Timing tool
  - Single-shot spectrometer
  - X-ray phase retarder

# Beamline assignment

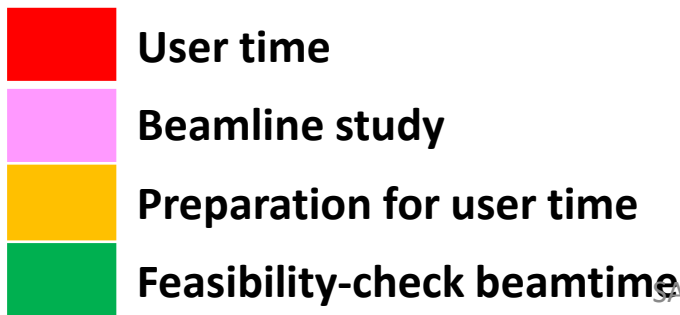
To XFEL users, the facility assigns BL2 or BL3 according to the type of experiment.

	Type of experiment	Instruments	Remarks
BL2	Fixed-target PX SFX CDI	KB ( $\sim 1 \mu\text{m}$ ) DAPHNIS (SFX) MAXIC-II (CDI)	Feasibility-check beamtime for SFX
BL3	Ultrafast XRD, WAXS, Spectroscopy  Nonlinear optics	fs laser Timing tool CRL, KB ( $\sim 1 \mu\text{m}$ ) 300 exa ( $\sim 0.1 \mu\text{m}$ ) SDO	Ultrafast measurements  Polarization control  Double-pulse XFEL

# Examples of weekly schedule



\* Double-pulse operation, 60 Hz operation, etc.

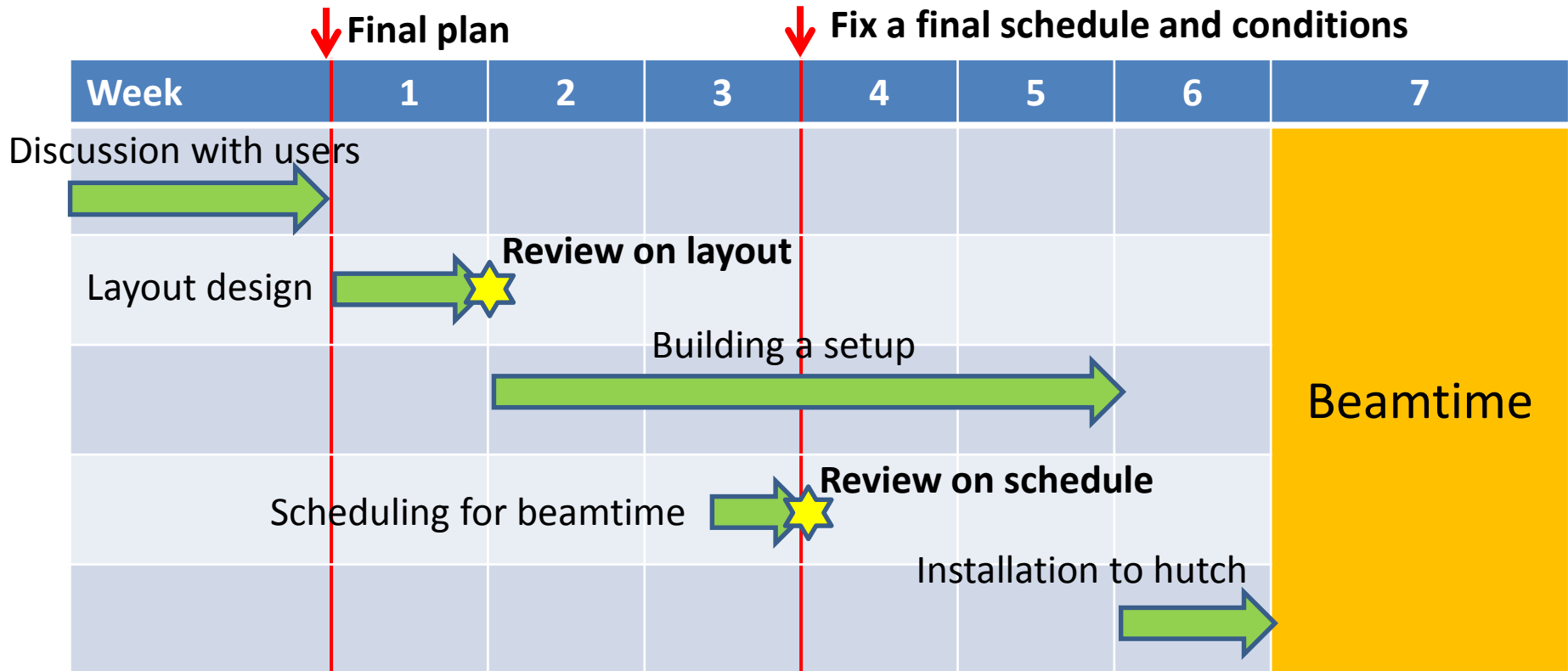


# For successful experiment

- Feasible planning is important especially under the multi-beamline operation.
  - Busy schedule.
  - To avoid conflicts between beamlines about instruments, sample-prep room, facility personnel, etc.
- Users are encouraged to discuss their experimental plans with the beamline staff *well in advance.*  
(sacra-bl.jasri@spring8.or.jp).
  - To secure enough preparation time.
  - Even in the stage of planning a proposal.
- Standard systems are useful for experiments by established techniques (SFX, CDI, WAXS, Spectroscopy)
- Feasibility-check beamtime by using DAPHNIS at BL2.

# Typical schedule for preparation by the facility staff

Well-planned preparation is a key to successful.



- Final experimental plan: *~6 week* prior to the beamtime.
- Final schedule and conditions: *~3 week* prior.

# Summary

SACLA XFEL beamlines are continuously upgraded.

- Strategic development of beamline optics and experimental systems.
  - Fundamental technologies
  - Standardization
  - Highly advanced applications
- Parallel operation of BL2 and BL3 offers more opportunities to users.
- Input from users is highly appreciated.