8th Hard X-ray FEL Collaboration Meeting
Oct. 24-26, 2016 (PAL, Korea)

Strategy for efficient and robust operation

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on behalf of SACLA beamline staff

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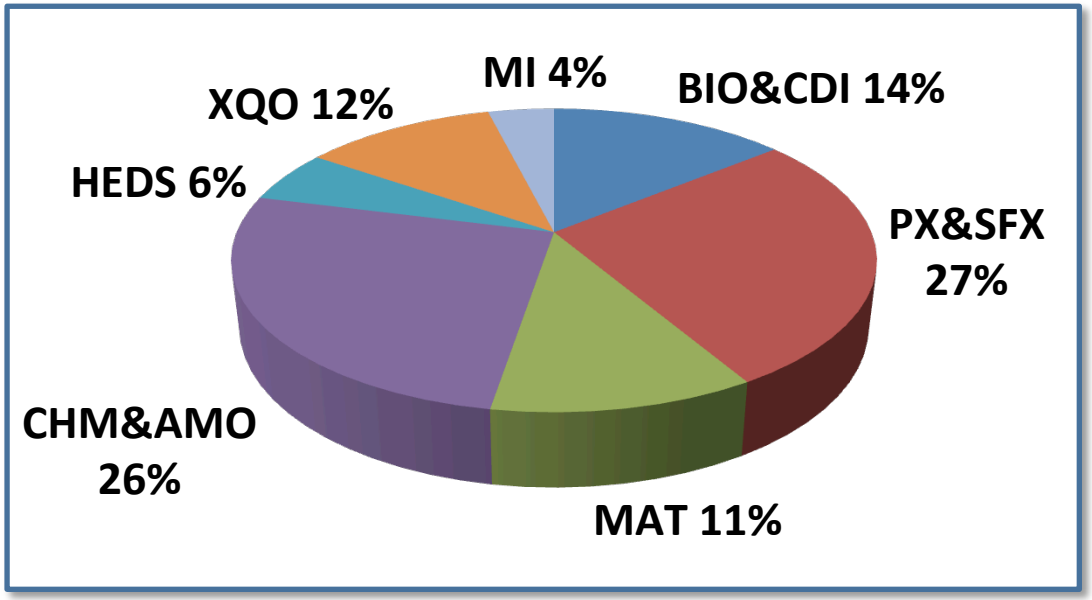
Efficient and robust BL operation is highly required.

Research fields at SACLA (FY2015)



BIO: Imaging biology

CDI: Coherent diffraction imaging

PX: Protein crystallography

MAT: Ultrafast materials science

CHM: Ultrafast chemistry

AMO: Atom, Molecule, Optical science

HEDS: High energy density science

XQO: X-ray quantum optics

MI: Methods and instrumentation

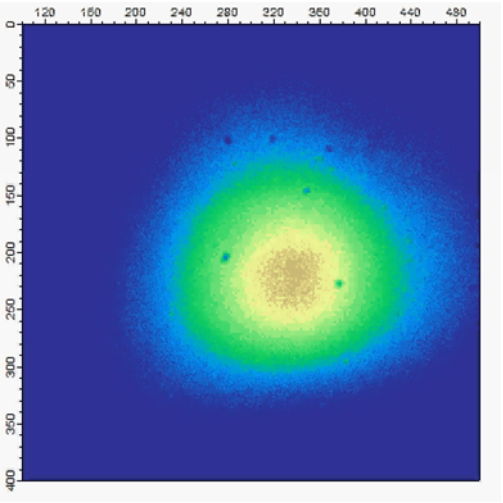
- Frequent changes in experimental setup and XFEL parameters for different types of experiments.
- Only 1 shift (12 hours) for *pre-beamtime* tuning.
  - X-ray optics, endstation instruments, pump lasers.
- We should prevent *accidental* re-tuning in beamtime (generally time consuming).

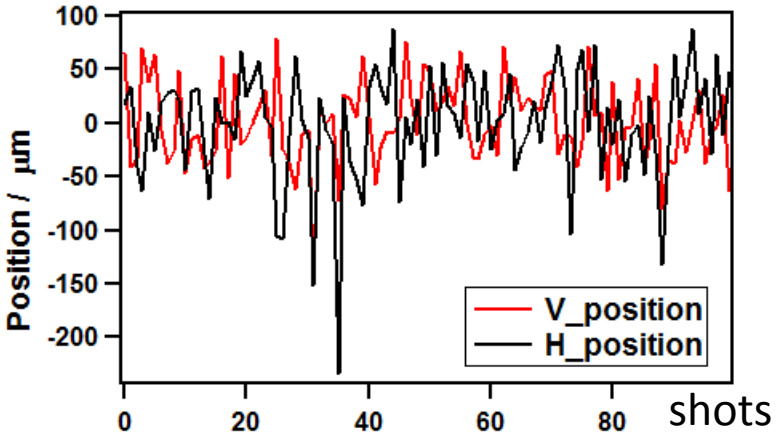
What are necessary for the efficient and robust operation?

1. Stable photon source.
2. Stable optics.
3. Reliable diagnostics.
   - In-line (non-destructive) diagnostics is more helpful.
4. *Reasonable procedures (protocol) for efficient and reliable tuning.*
   - *Both accelerator and beamline.*

Enhanced XFEL stability by improved temperature control

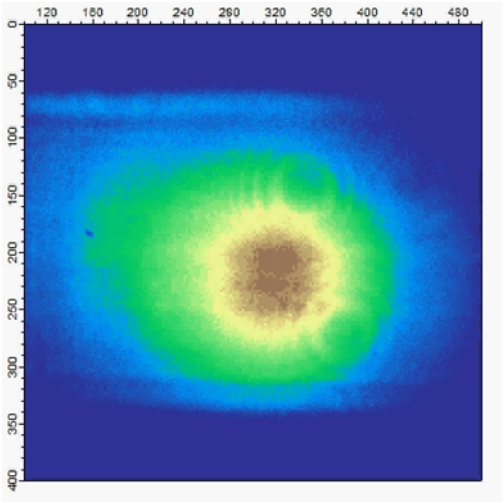
Before (July 25, 2012)

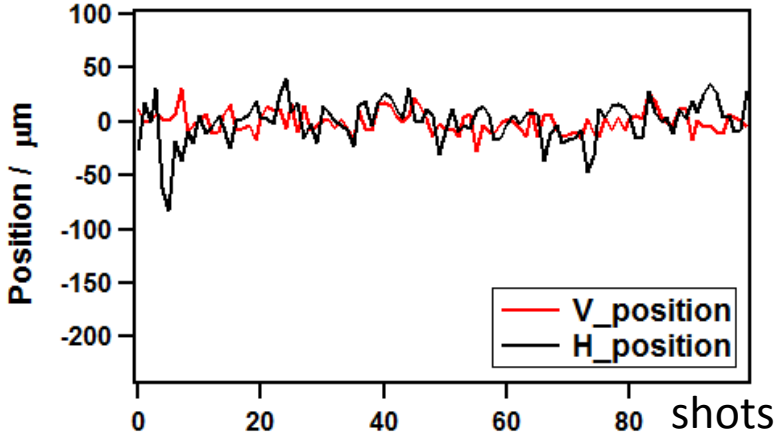




Vertical:±40 µm (S.D.)
Horizontal:±50 µm

After (Sept. 14, 2012)

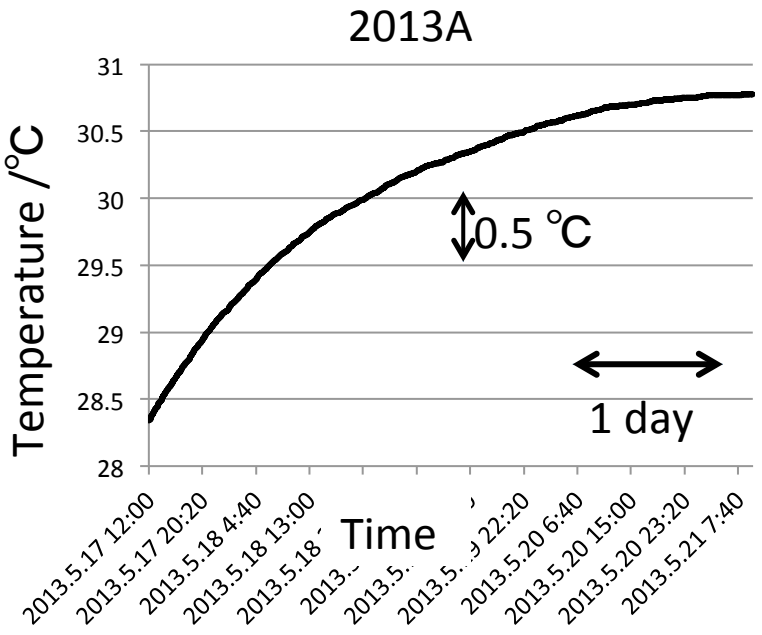


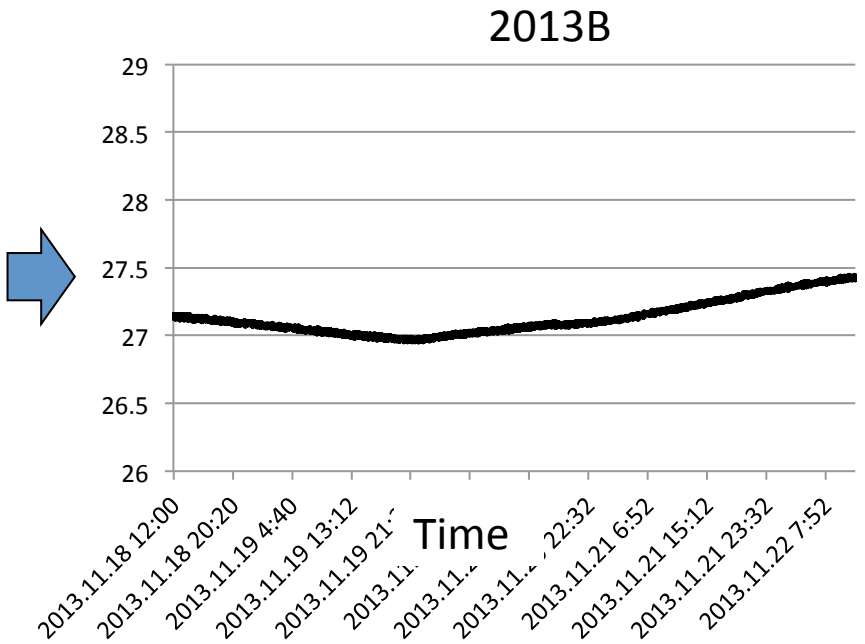


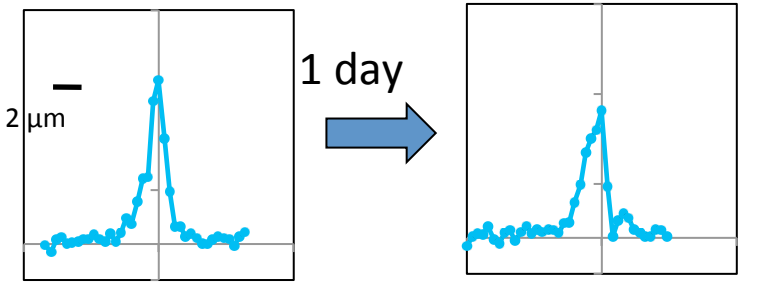
Vertical:±10 µm (S.D.)
Horizontal:±20 µm

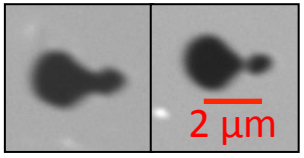
Stabilized KB optics by suppressing temperature drift.

(From the 7th workshop)

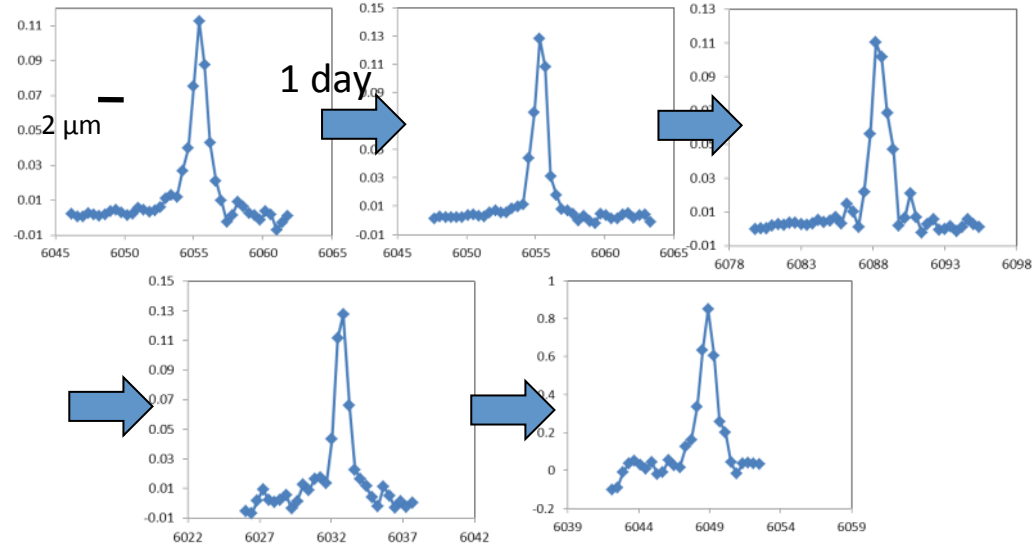








SiN membrane
after shot



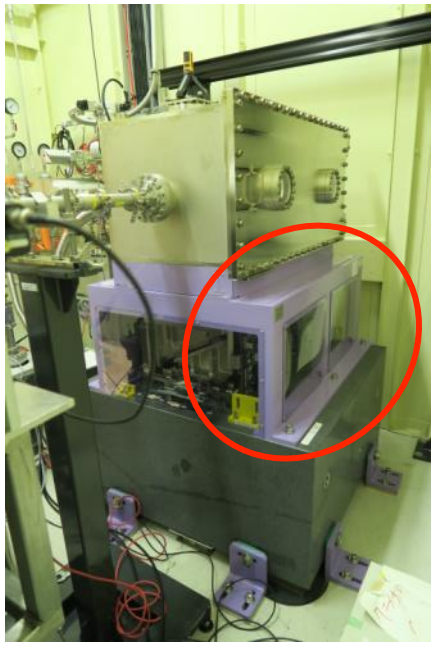
Courtesy of Prof. Nakasako

Enhanced KB stability against vibration

(From the 7th workshop)

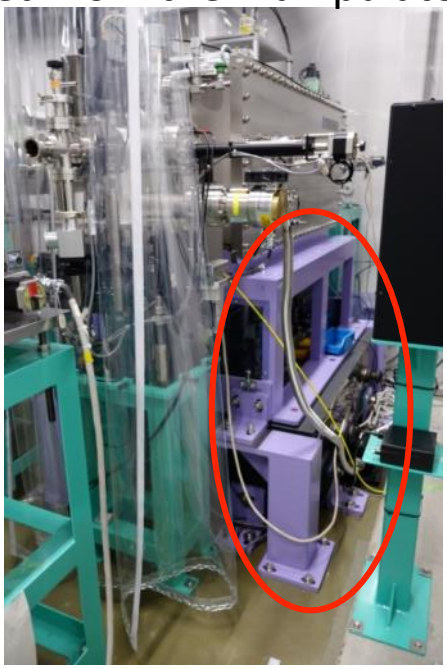
Both the manipulator and chamber were mounted on the same stone table.

Previous

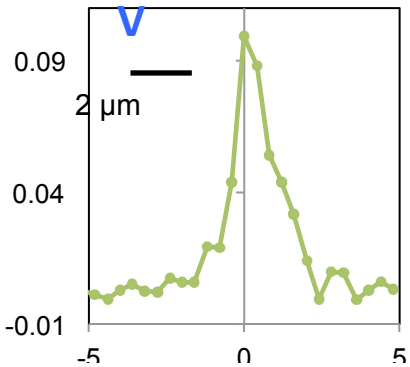


The chamber is supported on the ground, isolated from the manipulator.

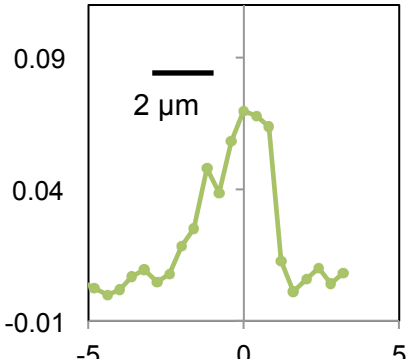
Current



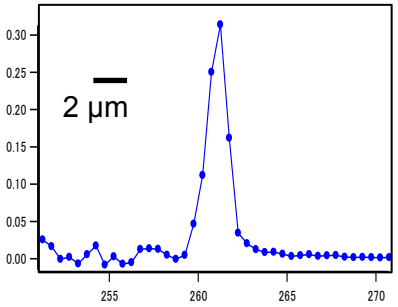
Air conditioner: OFF



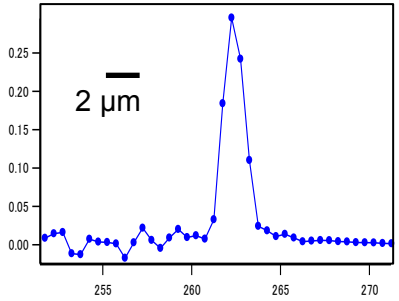
ON



Air conditioner: OFF

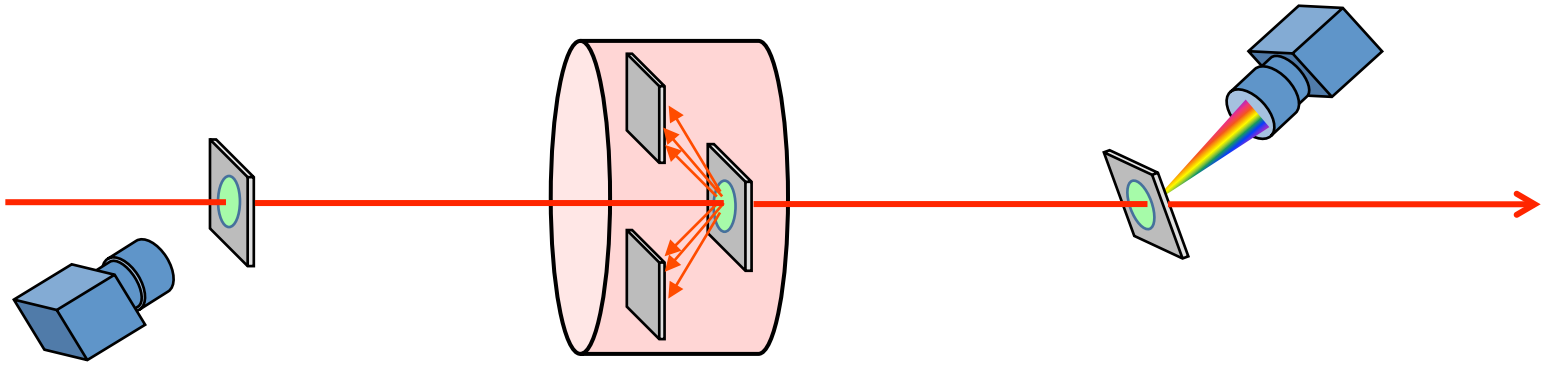


ON

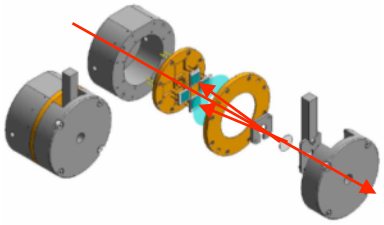


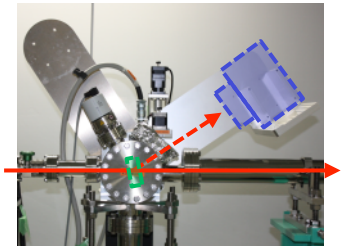
In-line diagnostics for efficient tuning

Non-destructive diagnostic tools using diamond foils (10-40 μm thick)



Profile & position | Intensity & position | Wavelength

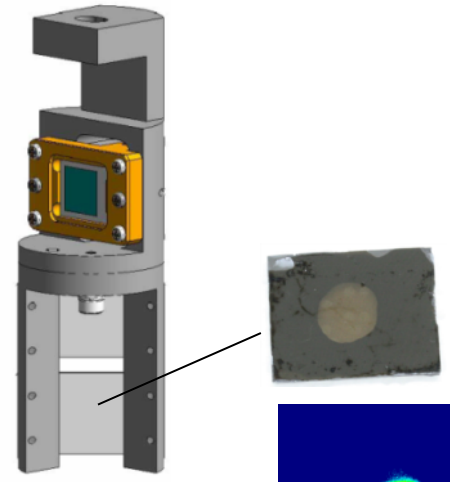


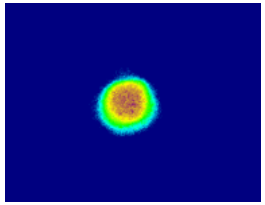


Photodiode

Ce:YAG

B-doped diamond





Beam-center position is reproduced within ±30 μm in the daily tuning.

~15 μm pixel resolution

K. Tono et al. New J. Phys. 15, 083035 (2013)

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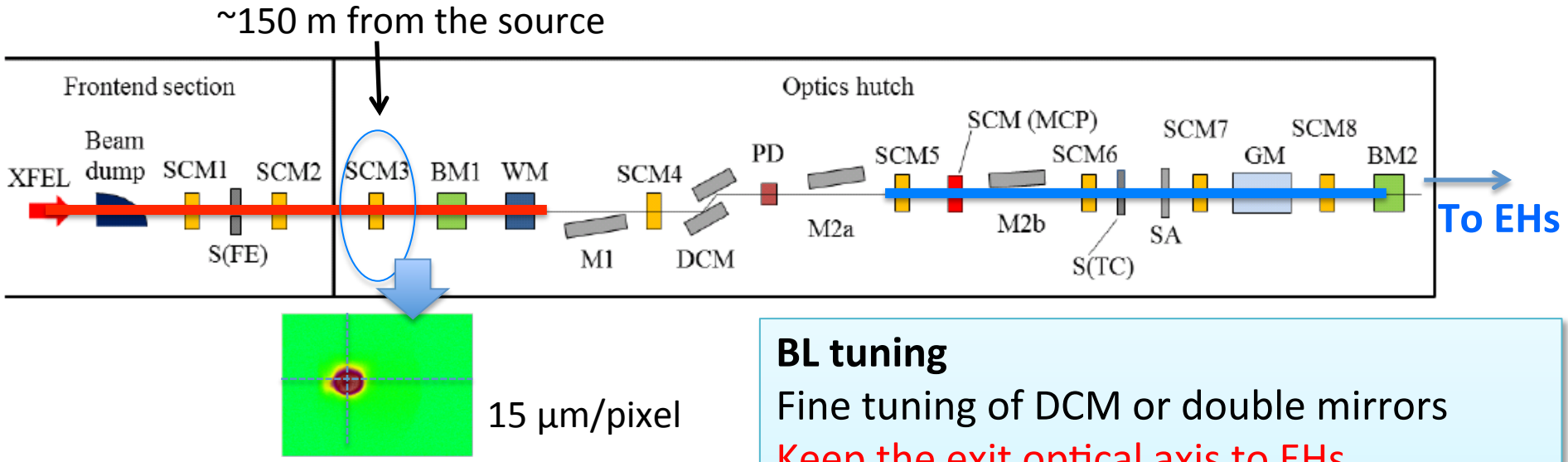
Procedures for routine BL tuning



Accelerator tuning

Pulse energy, beam profile, photon energy

Keep the incident X-ray beam axis

Check beam position on SCM3

≤2 pixels => ≤ 30 µm => ≤ 0.2 µrad

Fix the beam axis, not move samples to the beam

BL tuning

Fine tuning of DCM or double mirrors

Keep the exit optical axis to EHs

Check beam positions on SCM6, 8, 9, ...

Check beam properties

- Energy spectrum with DCM scan
- Beam profile with SCMs
- BL transmission with BMs

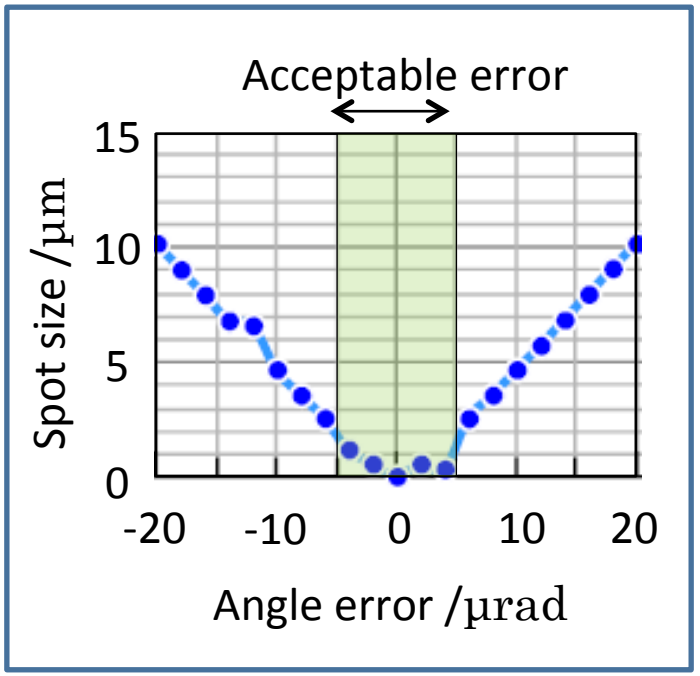
Tuning 1-µm focusing incl. knife-edge scan

Routing tuning is conducted by operators (Engineering Team), based on the protocols set by ACC & BL scientists

Fixing the beam axis makes the tuning more efficient.

- Fix the XFEL beam axis according to the tuning procedure.
- As a result, pointing error can be within ~0.2 µrad.
  - ~30µm position error at SCMs.
  - ~ 150 m from the source.
  - *Much smaller than the acceptable error of the 1 µm KB system.*
- No need for the elaborate tuning of the KB mirror.

Angle error vs. spot size of the 1 µm KB at SACLA



Protocol & typical operation time for routine tuning

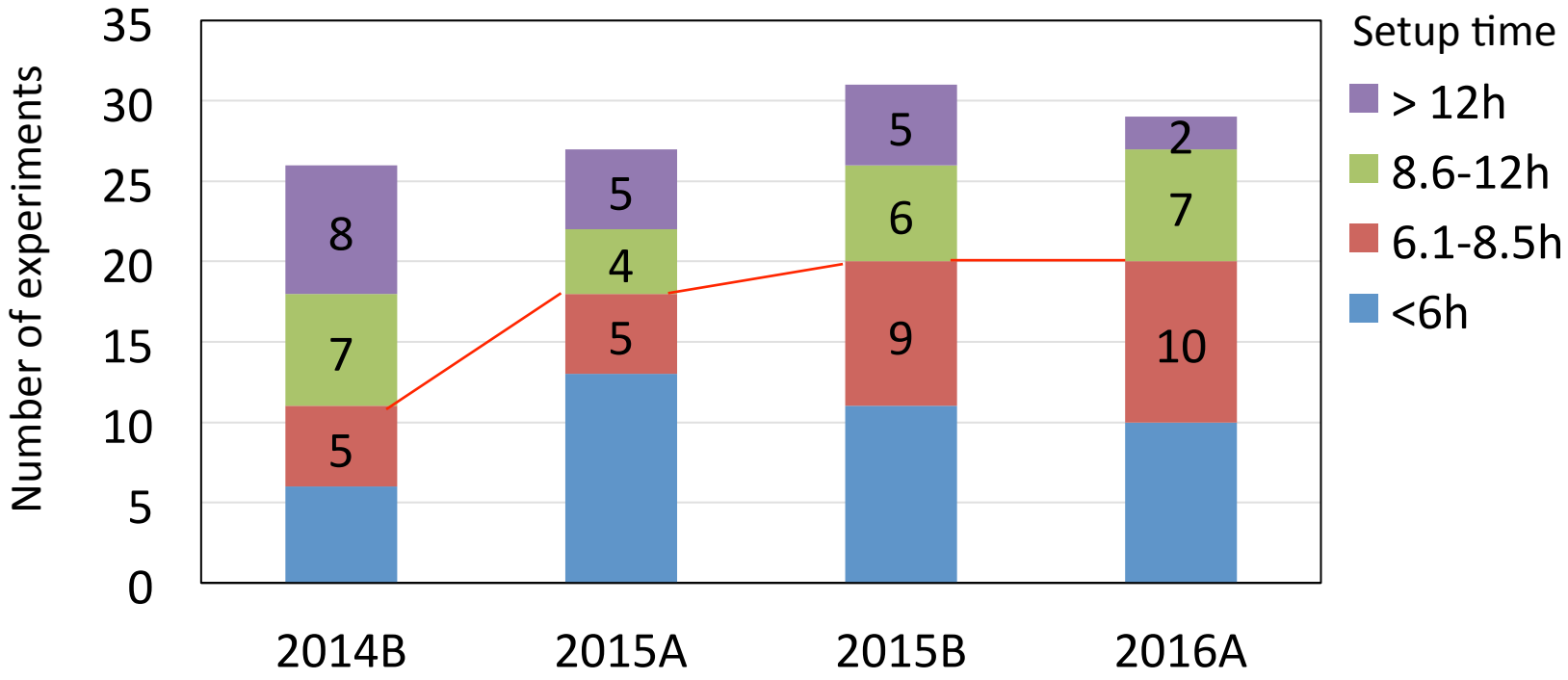
The tuning procedure was established.

Process		Time /minute		
		2013B	2014A	2015A
Accelerator	Tune beam axis	6	3	4
Beamline	Measure spectrum (DCM)	15	20	17
	Switch optics (from DCM to mirrors)	10	10	13
	Tune mirrors	23	12	14
	Focus X-ray with KB	~180	~120	45-90
Total		~234	165	93-138

Total setup time

- ~7 hours in average (2016A)
  - 3 h for installing experimental apparatuses to EH.
  - 2-3 h for BL tuning.
  - 1-2 h for others

    Accelerator tuning, tuning of instruments in EH, etc.
- For ~70% of the experiments in 2016A, the setup was finished within 8.5 hours. (Cf. ~40% in 2014B)



Summary

- It has been widely believed that an XFEL source is unstable and difficult to control.
- This may be true, as we could not expect high stability like synchrotrons.
- But there should still be a large room to improve the operation by setting up and optimizing "tuning protocol" for the accelerator and beamline.

Thank you for your attention !