Experimental platform using 100-nm focusing optics

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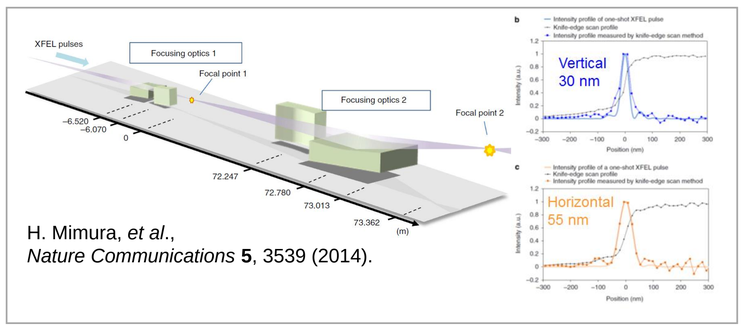
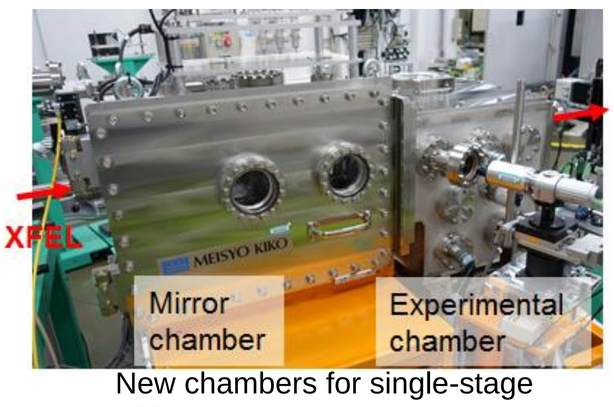
Introduction

Two-stage focusing system (Old)

- Designed before SACLA lasing
  Source point is assumed to be the exit of the last undulator line
  ← Actual source point is center of undurator line
- Throughput: < 10%
- Previous focus: ~ 50 nm ⇒ But, recently > 100nm
- Difficult tuning（~ several hours）, but short lifetime of good condition（~ a few hours）



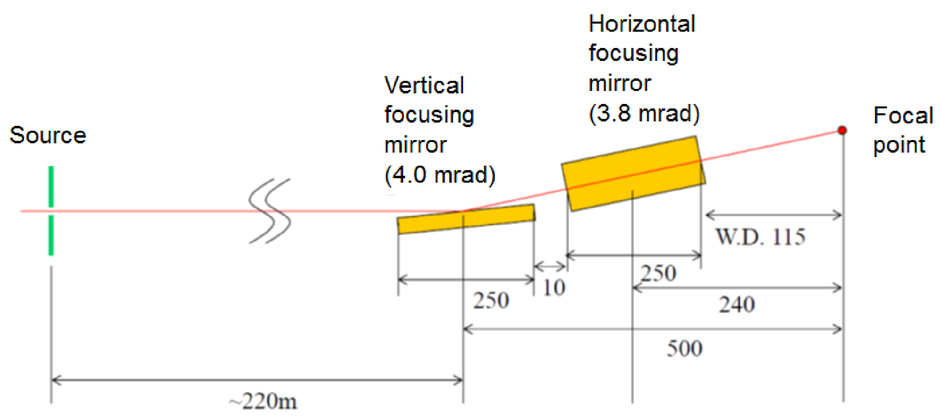
H. Mimura, *et al.*,
Nature Communications **5**, 3539 (2014).



New chambers for single-stage 100-nm focusing system

New 100-nm focusing system (one-stage) based on current status was installed in summer 2017.

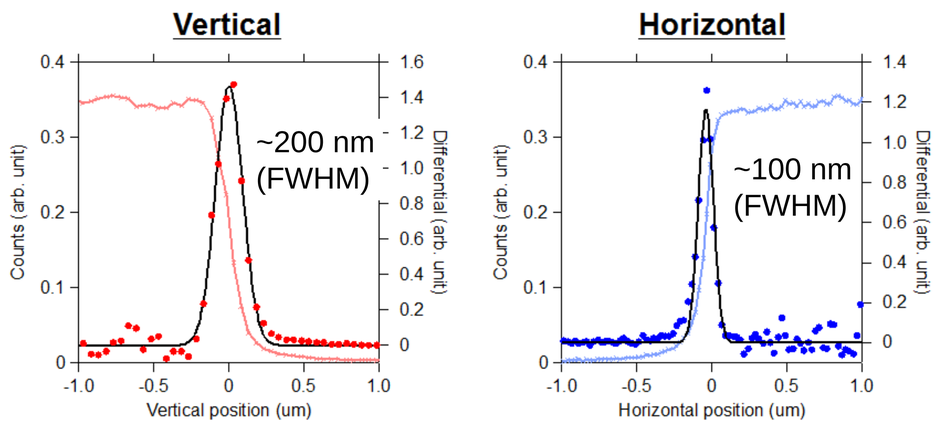
Design of optics



Upstream mirror
- Focal length: 220.000 m, 0.500 m
- Incident angle: 4.00 mrad (mirror center)
- Mirror length: 250 mm
- Spatial acceptance: 1000 μm
  ⇒ Diffraction limited focus size:
  ~45 nm (FWHM) at 12 keV

Downstream mirror
- Focal length: 220.000 m, 0.240 m
- Incident angle: 3.80 mrad (mirror center)
- Mirror length: 250 mm
- Spatial acceptance: 950 μm
  ⇒ Diffraction limited focus size:
  ~23 nm (FWHM) at 12 keV

Focus size and intensity



The new focusing system is stable and easy for alignment.

Pulse energy after KB optics: ~150 μJ
= 600 μJ x 0.25 (throughput to focal point)
Focal spot: 200 x 100 nm²
Pulse duration: 8 fs
⇒ **~ 10^{20} W/cm²**

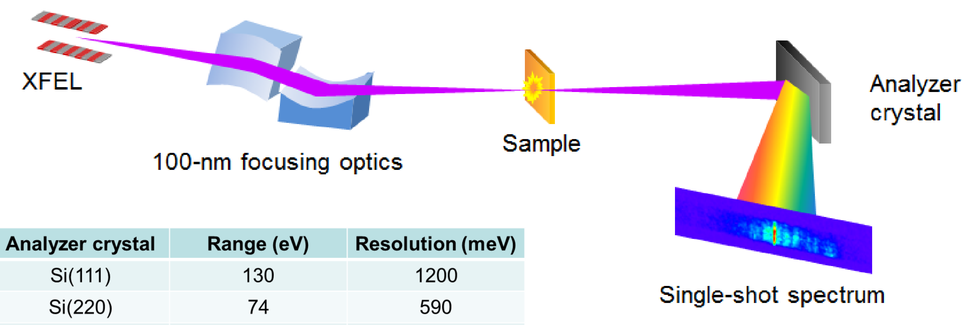
Comparison of focusing systems

	2-stage focus (old)	New 100-nm focus
Typical focal size (9 keV)	~90 nm (H) ~120 nm (V)	~100 nm (H) ~200 nm (V)
Intensity (pulse energy: 600 μJ, duration: 8fs)	~ 6 x 10^{19} W/cm²	~ 10^{20} W/cm²
Throughput (including reflectivity)	< 10%	~ 25%
Tolerance of incident angle	~ 0.2 μrad	~ 1 μrad
Rayleigh length	~ 50 μm	~ 30 μm
Cut-off energy	15 keV	12 keV
Time for focus alignment	Several hours	~ 1-2 hour
Lifetime of focus	A few hours	> 10 hours

Diagnostics

Single-shot spectrometer

Applications:
XFEL-pumped Kα laser,
X-ray saturable absorption, etc.

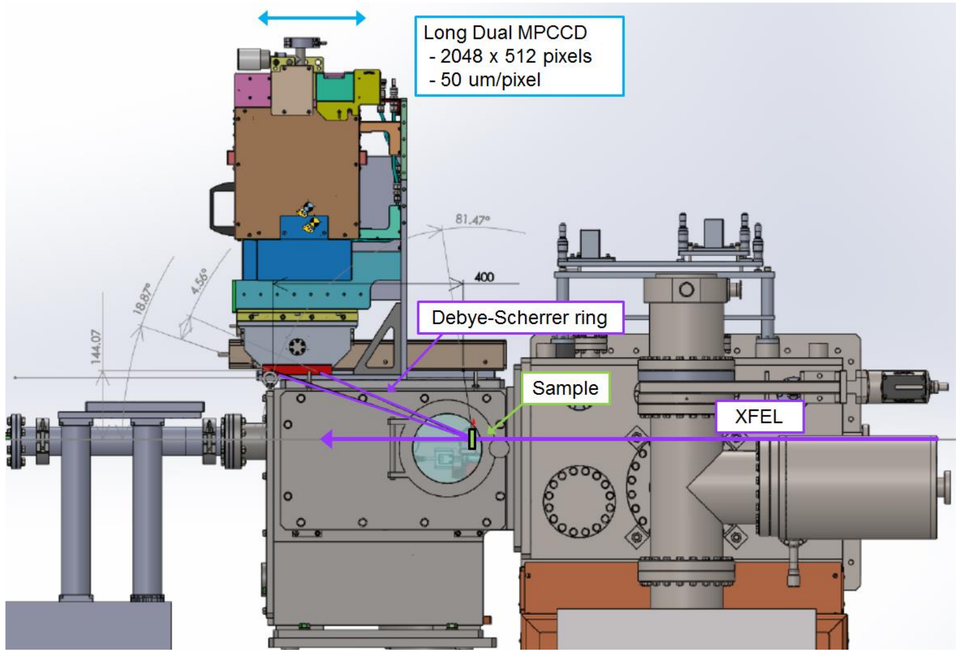


Analyzer crystal	Range (eV)	Resolution (meV)
Si(111)	130	1200
Si(220)	74	590
Si(311)	60	370
Si(331)	41	230
Si(333)	30	150

8.05 keV (Cu-Kα), Distance from sample to detector: 2.5 m

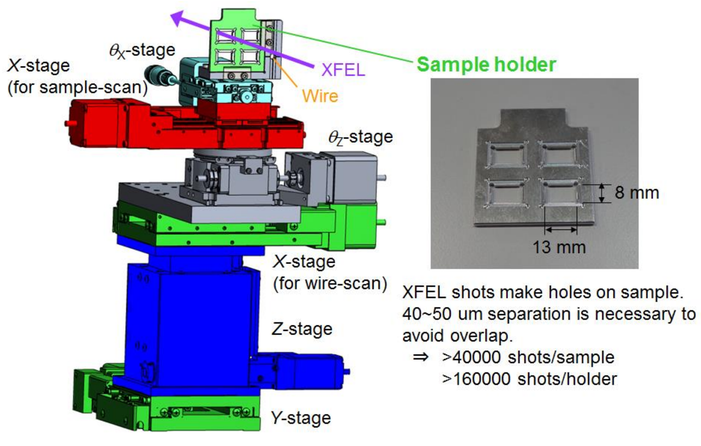
X-ray diffraction measurement

Applications:
fs-damage measurement, etc.



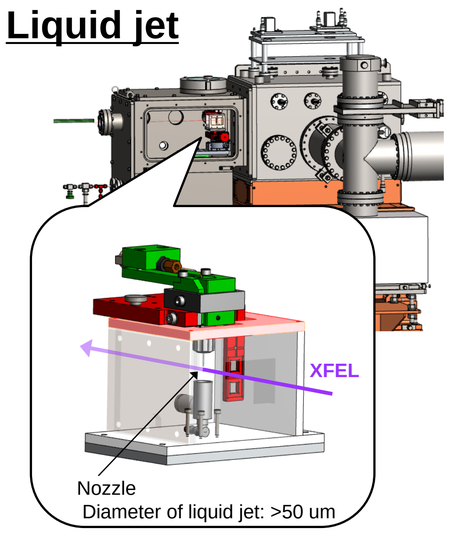
Sample systems

Foil



XFEL shots make holes on sample.
40~50 um separation is necessary to avoid overlap.
⇒ >40000 shots/sample
>160000 shots/holder

Liquid jet



The liquid system will be available in early next year.

Summary

New 100-nm focusing system (one-stage) based on current status was installed in summer 2017.
The new focusing system is stable and easy for alignment.
XFEL intensity of 10^{20} W/cm² was achieved.
User friendly sample system for solid foil and liquid jet has been developed.
The system has extensibility for many types of experiments.
A lot of unique studies are expected by combination use with self-seeded XFEL and/or 2-color XFEL.