Current status and development of nanofocusing system at SACLA

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2-stage nanofocusing system (50 nm and sub-10 nm)
- Large demagnification factor with compact facility
- High NA with small divergence of XFEL
- Unique X-ay sciences were investigated using the 50 nm focusing system.

However,
- Designed before SACLA lasing
- Source position was assumed to be the exit of last undulator.
- Difficult tuning, but short life time of fine focus
- Throughput < 10% (Slightly small acceptable aperture)

One-stage nanofocusing systems (300 exa & new sub-10) have been developed.

300 exa: 100~nm focusing system (Installed in summer 2017)

Optical design
- The system consists of 1-stage KB optics.

Typical focusing profile @ BL3 (EHS)
- Upstream mirror (Vertical)
  - Source-mirror distance: 220 m
  - Focal length: 500 mm
  - Incident angle: 4.0 mrad
  - Mirror length: 250 mm
  - Spatial acceptance: 1 mm
  - Numerical aperture: 1.0 \times 10^{-5}
  - Focus size (diffraction-limit): 45 μm @ 12keV
  - Demagnification factor: 440
  - Focus size (geometrical): \approx 180 nm
  - Focus size (total): \approx 200 nm

6052~8.6~errors measured by grating

Diffraction measurement:
- Factor of 6000~ is necessary.
18.9

Multilayer

7.2

Sample:
- Mirror length: 250 mm

Focus size (average): 200 nm (V)
- Numerical aperture: 2.4
- Target: (source size: 10 nm)
- Time: \approx 2 hours
- Sample: Foil, Liquid jets, Gas chamber, etc.

Results of 1st commissioning @ SPring-8
- 1-dimensional (horizontal) focusing test was performed.
- Alignment time was \approx 2 hours with good repeatability and stability.
- Shape accuracy of mirror was 4~5 nm PV, characterized by grating-interferometer.
- Goal is \approx 1 nm PV. Mirrors will be re-polished.

3.2

Spatial acceptance: 0.95 mm

W.D. 43.1

Focus size (total): \approx 100 nm

Optical setup of 50 nm 2-stage KB focusing system
– Vertical focusing mirror (40 mrad)
– Horizontal focusing mirror (3.6 mrad)
– Focal point

Arrangement of sub-10 nm 2-stage KB focusing system
– Total mirror: KB mirror
– Multilayer 90 mirror

New sub-10 nm focusing system (under development)

Optical design
- The system consists of 1-stage Wolter III-advanced KB optics

Coma-corrected system
- Advanced KB mirror (Walter)

Schematic of old (2-stage KB) system
- 10°~10°

Compact but large damag.

Schematic of new (1-stage advanced KB) system
- To focus the XFEL source (~60 μm) down to 10nm.
- Damag, factor of ~6000 is available with the ~145 source-mirror distance in new system.

Results of 1st commissioning @ SPring-8
- 1-dimensional (horizontal) focusing test was performed.
- Alignment time was \approx 2 hours with good repeatability and stability.
- Shape accuracy of mirror was 4~5 nm PV, characterized by grating-interferometer.
- Goal is \approx 1 nm PV. Mirrors will be re-polished.

Mirror shape error estimated by measured wavefront
- Shape error on the KB mirror

0.5 μm

Calculated focusing intensity based on measured wavefront

Mirrors are still under developments. The system will be installed to BL3 (EH4c) in 2020 summer~.

Unique studies are expected
- Nonlinear X-ray physics: XFEL-pumped Ka laser, X-ray saturable absorption, etc.
- Diffraction measurement: fs-damage observation, etc.