Undulator Adjustment with the K-monochromator System at European XFEL

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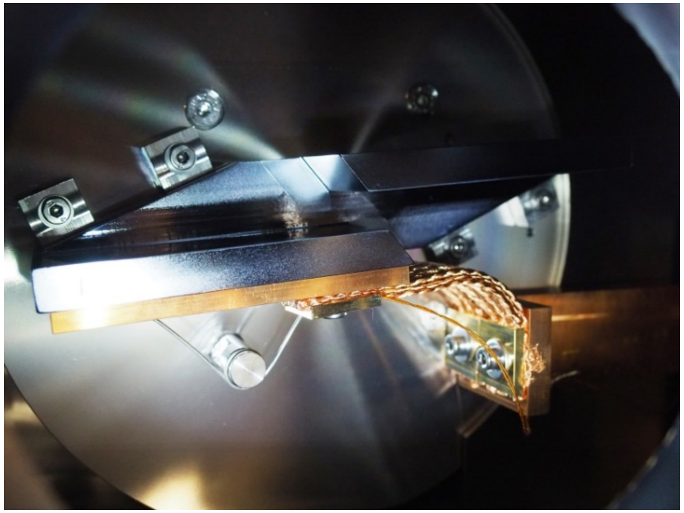


Further details:
„First measurements with the K-monochromator at the European XFEL ", Freund, W., Fröhlich, L., Karabekyan, S., Koch, A., Liu, J., Nölle, D., Wilgen, J. & Grünert, J., J. Synchrotron Rad. 26,1037-1044, (2019)

Introduction

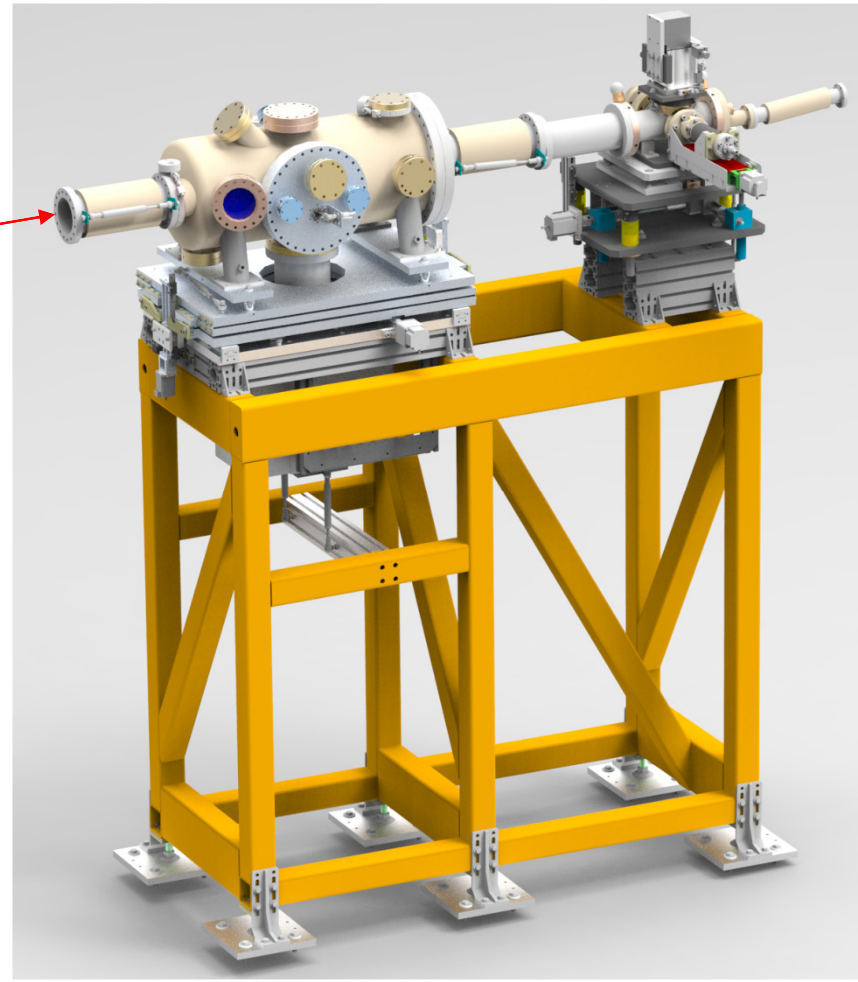
Main Purpose of the K-Monochromator (K-mono) system:

Very restricted means of magnetic measurements in the tunnels

→ Photon based measurements of undulator parameters

- Measurement of undulator K-value (single segments):
  Measuring the energy spectrum or energy distribution of the spontaneous radiation
- Vertical alignment of undulator segments:
  Measuring the K-value in dependence of the vertical offset position of an undulator cell
- e-beam orbit correction:
  Direct visibility of beam pointing, complementary to e-beam position measurements
- Others:
  - FEL spectra
  - Energy filter for calibration purpose

K-monochromator system

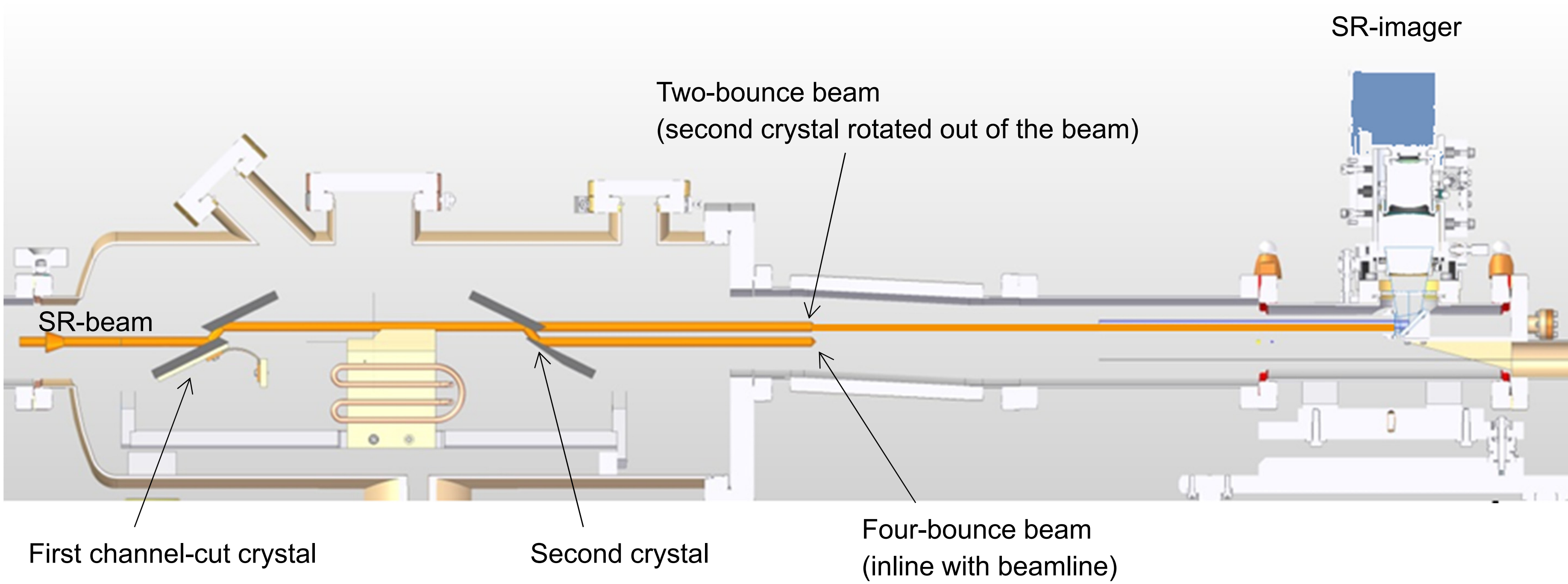


Material	Thickness	K-edge
Aluminum (light blocker)	2.5 µm	(1560 eV)
Copper	10 µm	7709 eV
Nickel	5 µm	8333 eV
Molybdenum	20 µm	20 keV

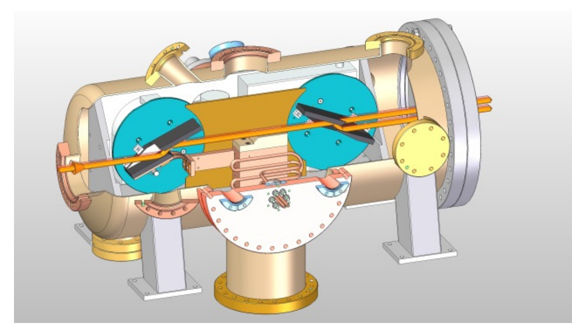
One K-mono system for each SASE beamline

J. Synchrotron Rad. **26**, 1037-1044 (2019)

K-mono setup

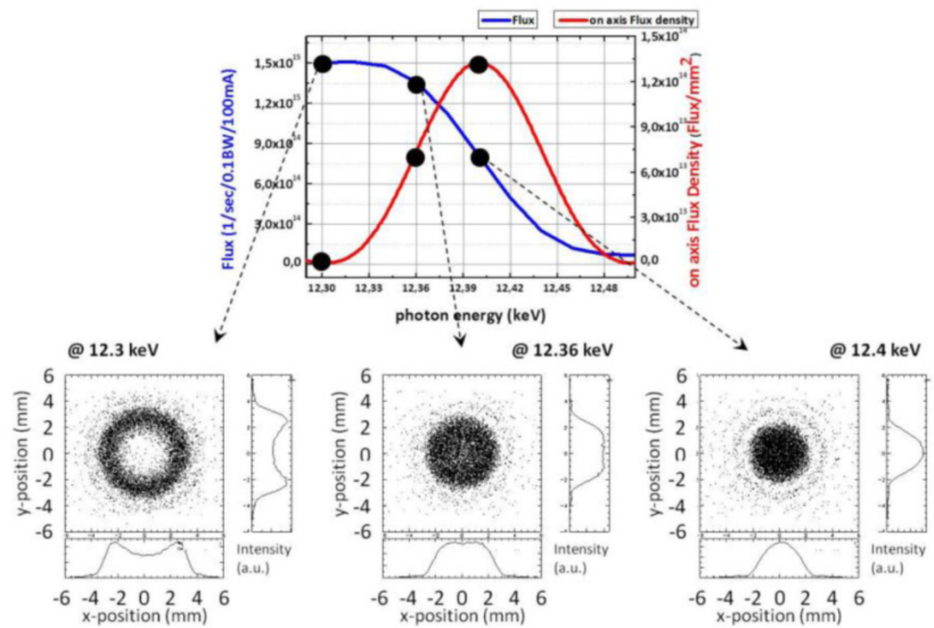


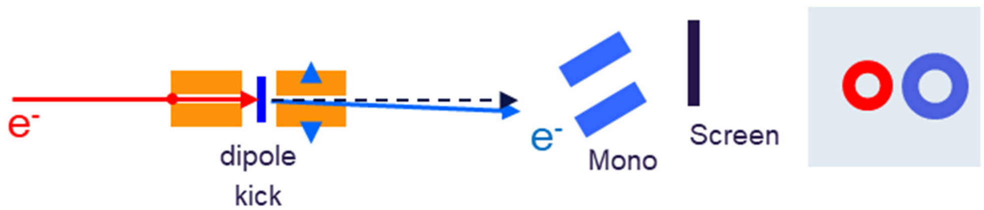
Specifications	
Crystals	Two Si(111) channel-cut crystals
Bragg angle	~7° to 55°
Energy range	2.5 to >16 keV for Si(111) 7.5 to 48 keV for Si(333)

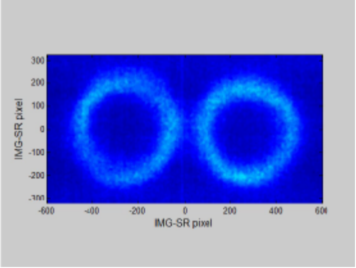


Methods for single undulator adjustment

- Integrated intensity (single segment)
  - Scan of Bragg angle or e-beam-energy
  - Photodiode detection
- Spatial profile of SR (‘donut’ diameter)
  - Slightly below resonance → ring (donut) diameter → K
  - Center of mass → pointing
- E-beam kick: two adjacent segments
  - Horizontal kick between the segments
  - Direct comparison of spatial profile







SR-Imager view of rings from two undulator segments with kicked e-beam

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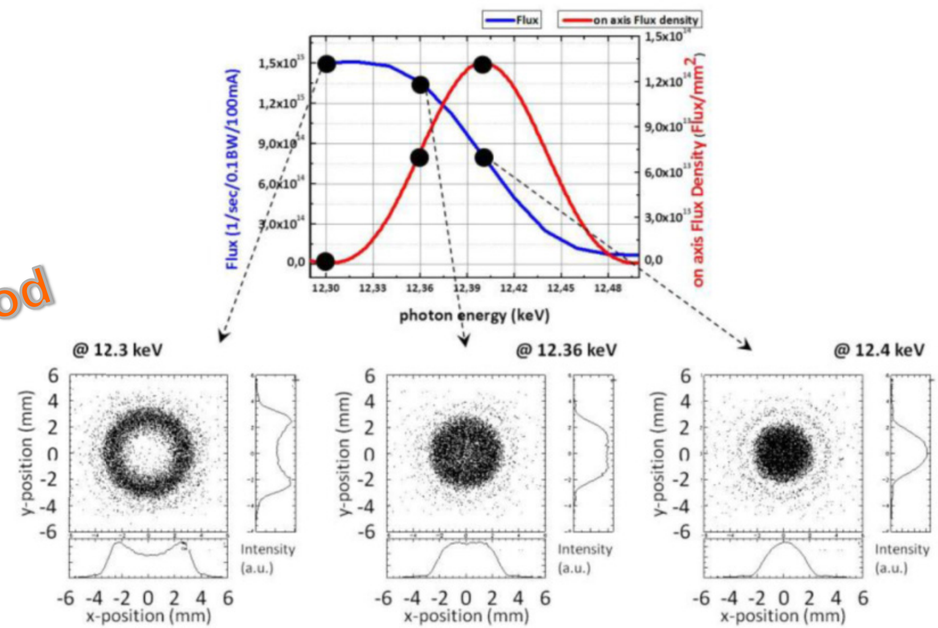
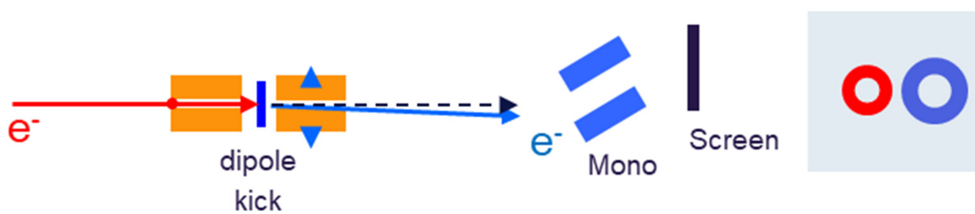
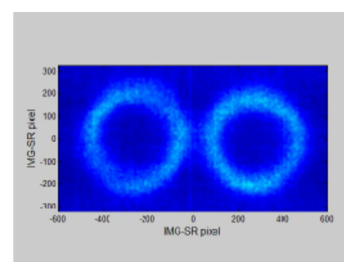
Preferred method







SR-Imager view of rings from two undulator segments with kicked e-beam

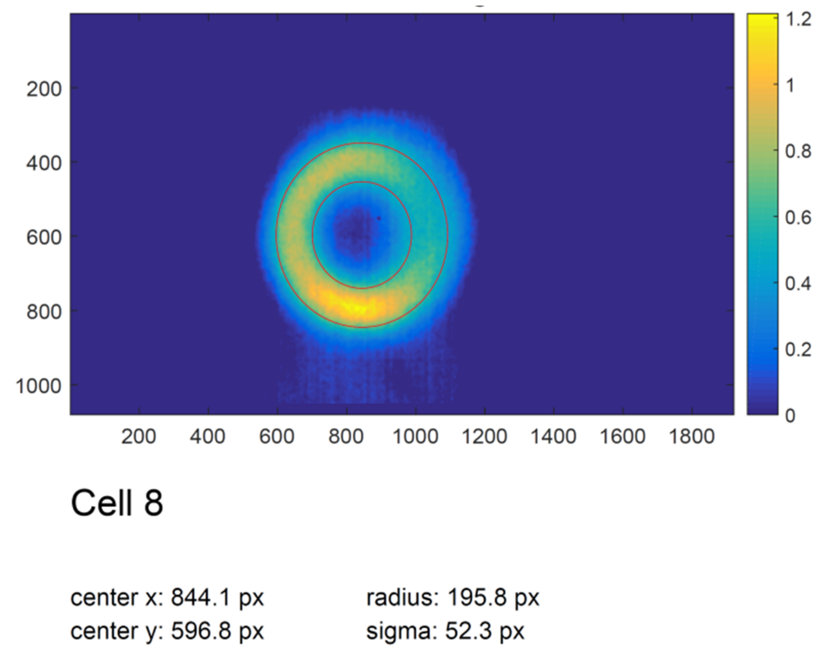
K-value determination

- Spatial profile of SR ('donut')
  - Observing the undulator radiation slightly below resonance
  - A ring appears: (hor.) diameter is a direct measure for the observation angle Θ
  - K can be determined from the undulator equation

Undulator equation: $\lambda_n = \frac{\lambda_u}{2n\gamma^2}\left(1 + \frac{K^2}{2} + \theta^2\gamma^2\right)$

- 2D ring fit of processed images:
  - Radius → K-value
  - Centre of Mass → pointing
  - Spatially integrated intensity → spectrum

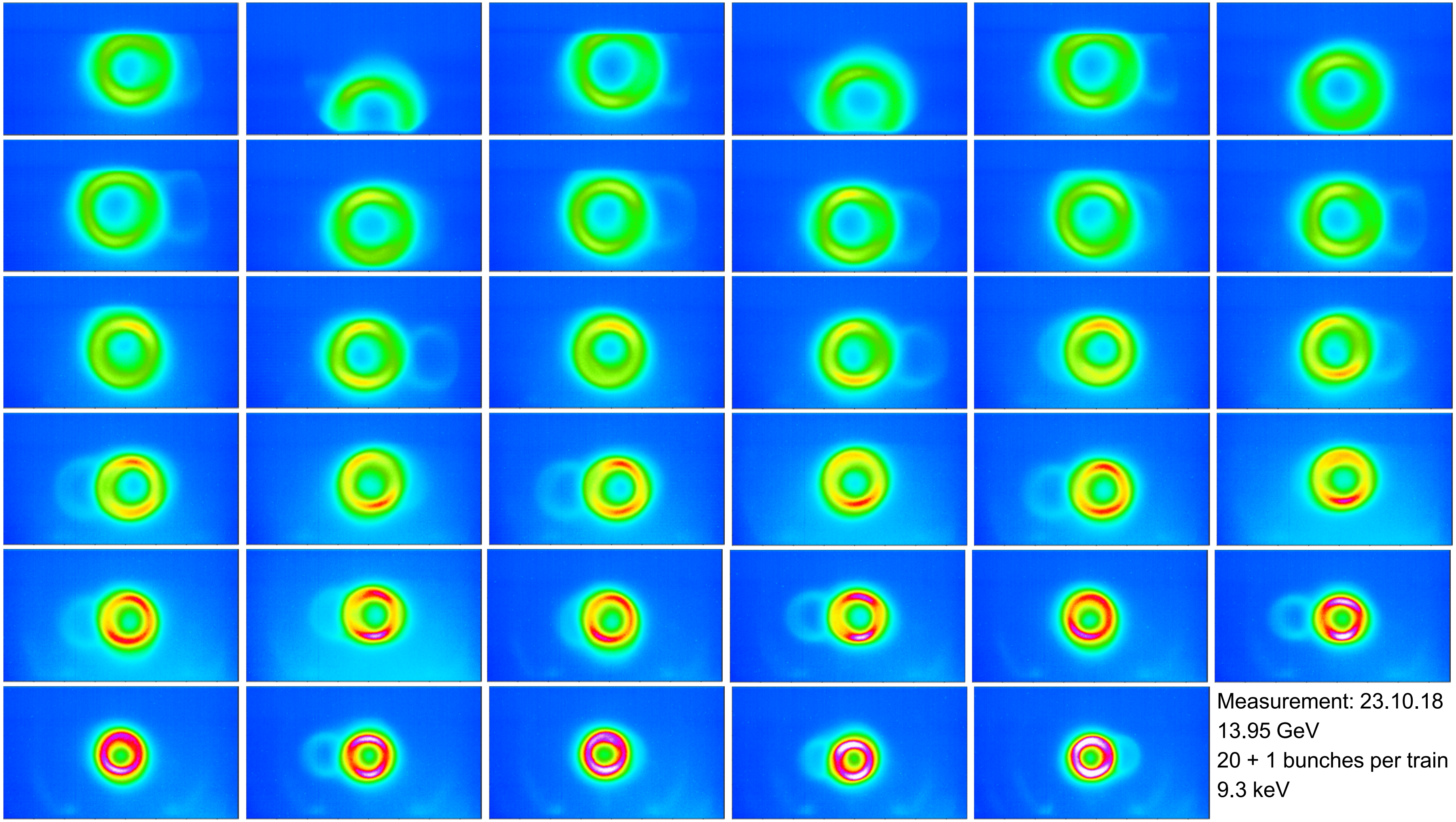
Ring fitting script developed by Lars Fröhlich from DESY MCS group



2D-ring fit of processed image

SASE1 undulator K-scan

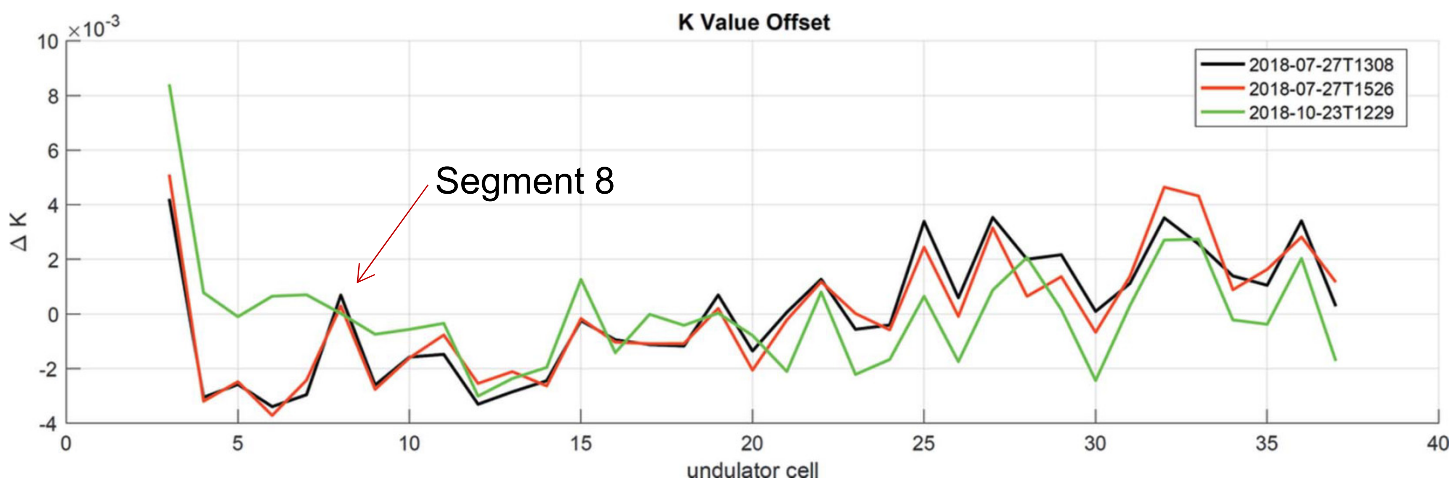
e-beam well optimised for lasing, one SASE3 bunch on a non-lasing orbit



Measurement: 23.10.18
13.95 GeV
20 + 1 bunches per train
9.3 keV

SASE1 undulator K-scan

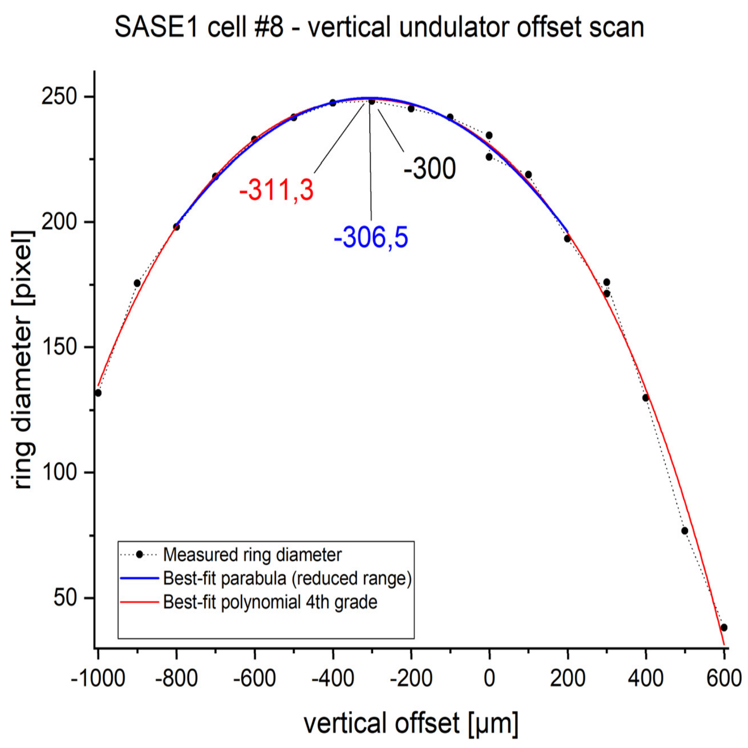
- Two independent measurements (repeated after 2 h) in July 2018: black and red curves
  Slope is due to a residual linear taper
- Repeated in October after the vertical alignment of segment 8 (green curve)
- Good correlation with 3 month between the measurements
- The automated K-scan routine takes less than 45 minutes for all 35 segments



Vertical offset measurements

We have tested the vertical adjustment procedure for several cells of the SASE1 and SASE2 undulator systems.

- Script in DOOCS: automated vertical offset scans of individual undulator segments
- Matlab script: 2D fit on the images → centre of mass (pointing) and ring diameter (K-parameter)
- After the scan: vertical undulator position could be set to where the maximum ring diameter was found
- Time for a single undulator segment adjustment scan: less than 10 minutes

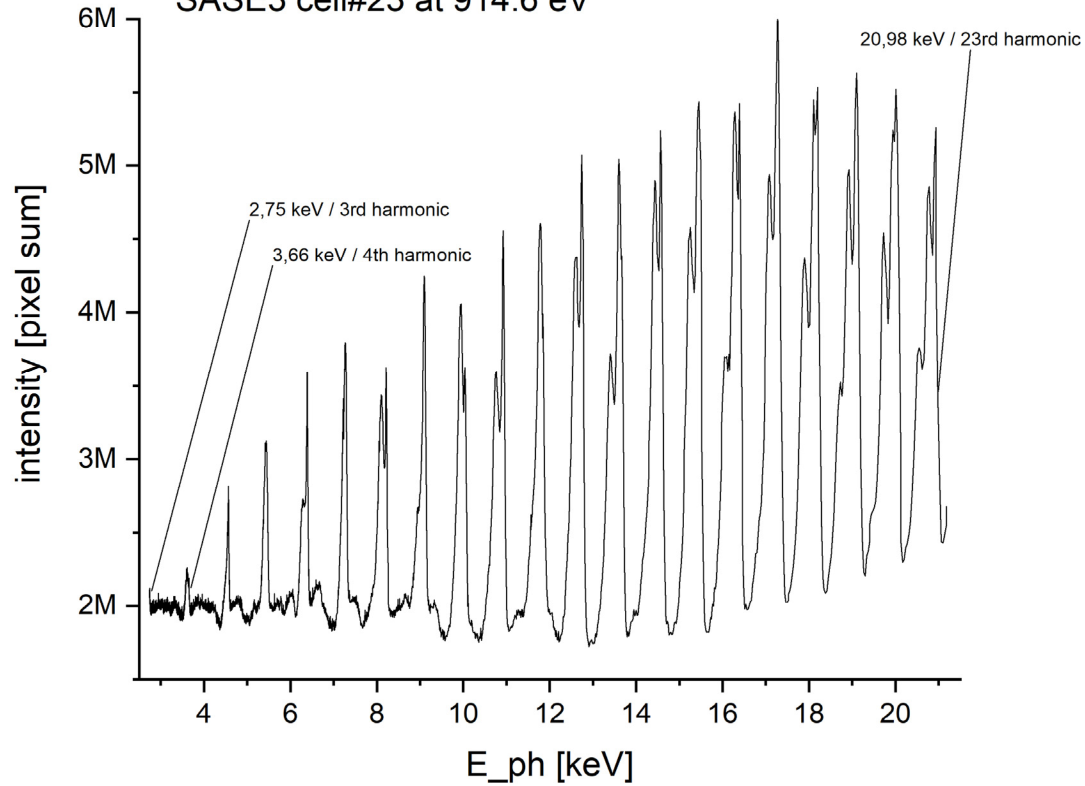


Scan of undulator harmonics (here: soft x-rays)

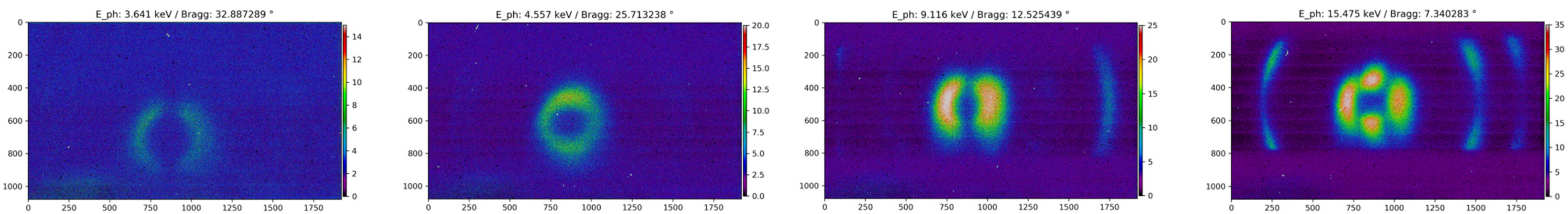
SASE3 K-mono

- Fundamental can not be detected
  → detection of harmonics
- Absolute energy calibration from harmonics
- Setpoint at nominal 900 eV measured 914.6 eV

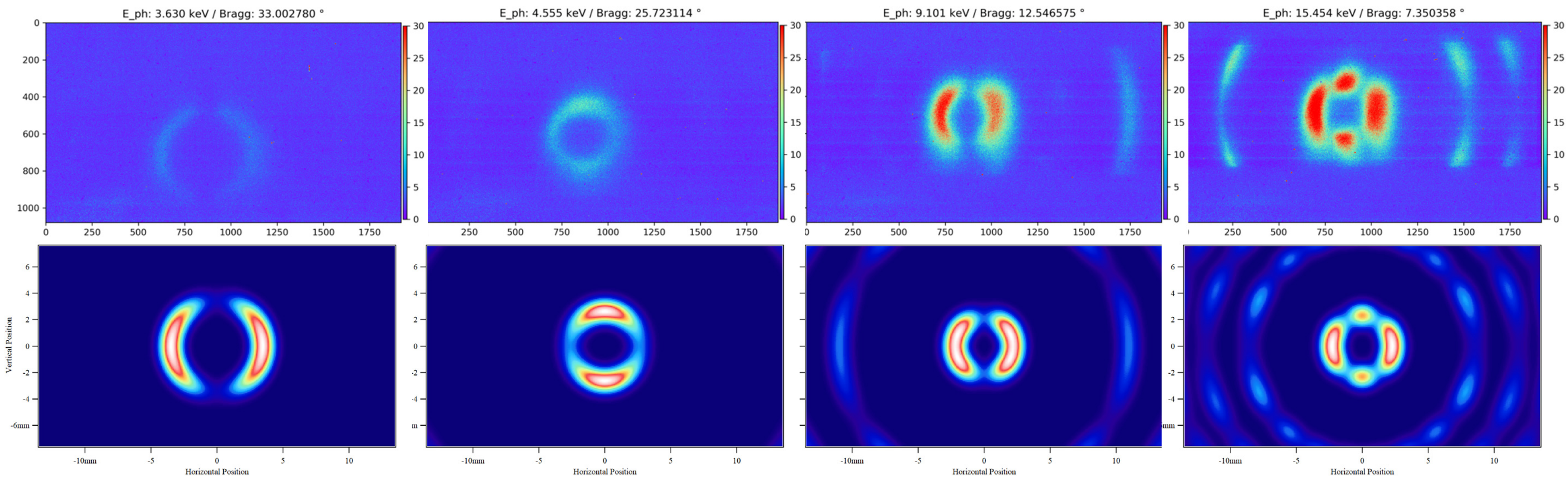
Spectrum from K-mono imagescan run021
SASE3 cell#23 at 914.6 eV



Harmonics: 4th, 5th, 10th, 15th



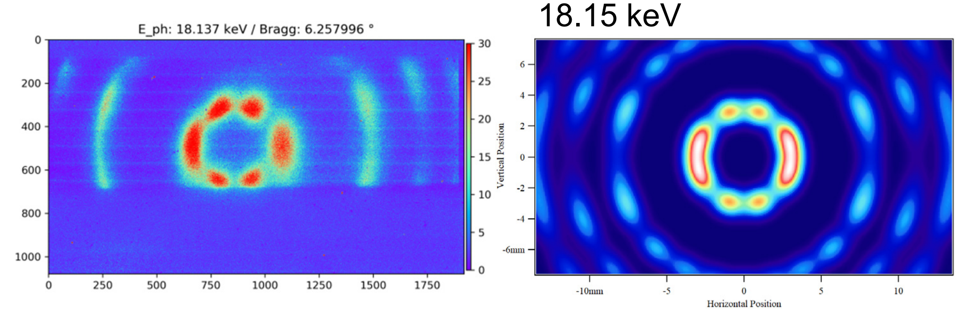
Comparison to SRW simulation



3.62 keV | 4.55k eV | 9.1 keV | 15.48 keV

- Measurement and simulation of SA3 cell 23
- e-beam: 14.08 GeV, 30 bunches

18.15 keV



Synchrotron Radiation Workshop (SRW):
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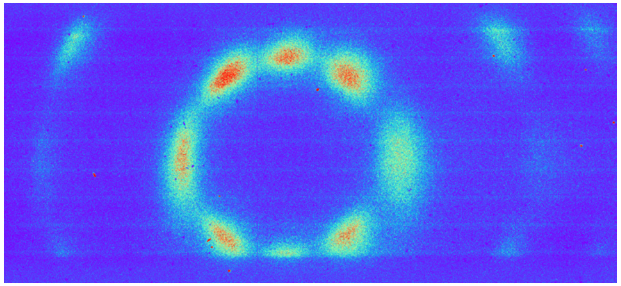
Conclusion and outlook

- In SASE1 and 2 the imaging methods are used for K-value scans and vertical magnetic middle plane scans → undulator K offsets are used for more stable settings
- Good e-beam conditions are necessary (especially orbit and low energy spread) for undulator alignment (it is possible to control the energy spread independently for north and south branch)
- Excellent hardware performance of monochromator and imaging system
- Further developments: control and DAQ software, more automated procedures (so that any trained operator can use the system)
- Regular undulator re-measurements of reference segments
  → helpful for assessment of radiation damages
- Further tests of 4-bounce mode: transfer of beam to downstream imagers or experiment

Thank you for your attention !



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