CONCEPTUAL DESIGN REPORT
(MAIN DOCUMENTS)

The European XFEL Undulator Commissioning Spectrometer

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The European XFEL Undulator Commissioning Spectrometer

Conceptual Design Review

Document 2:

High-Level Use-Cases

Nov 24, 2010

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(Reviewers: J. Grünert)

This document describes the basic purpose of the Undulator Commissioning Spectrometer for the European XFEL.

EDMS Nr.: D00000001939861 Rev: B Ver: 2 Status: Approved Dat.: 8. Jun 2011

System setup

The commissioning spectrometer system consists of a crystal monochromator in Bragg geometry and a detection chamber behind the monochromator chamber. Depending on the position in the beamline (before or after the main attenuators), it may include a small upstream vacuum chamber with attenuator foils.

Purpose

The commissioning spectrometer, also known as K-monochromator, is mainly used with spontaneous radiation and selects a narrow bandwidth of the x-ray photon beam in order to tune the undulator segments. This process is called photon beam-based alignment and will minimize the difference in the undulator parameters K between undulator segments and optimize the phase between segments. The photon source could be a single segment, two adjacent segments, two distant segments, and up to all undulator segments at once. For single or few segments and to increase flux, pulse trains of spontaneous radiation could be used, while for a system setup where lasing is possible, only single light pulses at 10Hz (single pulse operation) are allowed. The design must be consistent to allow for imaging of the weak single segment spontaneous radiation and on the other hand survive FEL radiation in single pulse operation for FEL diagnostics. The purpose of this diagnostics device is not to transport FEL radiation to users, but exclusively to tune the undulator to reach optimum FEL conditions.

With this instrument the spectral and spatial properties of the spontaneous radiation of single or multiple undulator segments can be investigated. By the use of absorbers or a low amount of bunches in a bunch train also the FEL can be observed.

This spectrometer will cover the main energy range of SASE 1 and SASE 2. In case of SASE 3 with its lower photon energy, the higher odd harmonics of the spontaneous (or FEL) radiation will be observed.

Tasks for the undulator commissioning spectrometer system:

a) Main purpose 1: relative adjustment of undulator segments (gap adjustment / K-parameter adjustment):
The system allows measurements of the photon energy of the spontaneous radiation of each undulator segment, in order to calculate and adjust the K-parameters to an accuracy which is required for FEL operation.

b) Main purpose 2: adjustment of the phase between undulator segments: intensity optimization by adjustment of the phase shifters between two adjacent undulator segments

c) observation of the monochromatized beam properties (profile, intensity)

d) spectral measurements of spontaneous or FEL radiation (averaged) by scanning the electron energy (fast) or by changing the crystal orientation (wide range)

e) trajectory adjustment:
spatial evaluation of higher harmonics of the spontaneous radiation, which have a smaller divergence than the fundamental

The European XFEL Undulator Commissioning Spectrometer

Conceptual Design Review
Document 3:
Requirements & Interface Definition

March 29, 2011

Amended version after CDR meeting from Dec. 2010

(Author: W. Freund)

(Review: J. Grünert)

EDMS Nr.: D00000001940111 Rev: B Ver: 3 Status: Approved Dat.: 8. Jun 2011

1 Requirements to the device

The requirements for this device derive from the undulator commissioning strategy described in chapter 4. The main basis for these calculations is the quadrupole kick method [2], which promises to be the fastest and most accurate solution. But the requirements of the other methods are also taken into account, in order to have a fallback solution.

1.1 Basic requirements

We are considering mainly SASE 1 and 2 specifications. The SASE 3 wavelength range can be covered by this spectrometer for the higher harmonic radiation, as the fundamental of the soft x-ray spontaneous radiation will have a too large divergence and would also not be transmitted by a crystal monochromator.

1.2 Measurement accuracy

For FEL operation it is not necessary to tune the absolute K value to a high accuracy, but all undulator segments must be tuned to the same K, so that the relative error in the produced wavelength is smaller than the pierce parameter:

$$\frac{\Delta\lambda}{\lambda} \leq \rho$$

The biggest variation of K will certainly be between different undulator segments, rather than within a single segment. So it is sufficient to measure and compare the K parameter between the segments.

$$K = \sqrt{2}\sqrt{\gamma^2\frac{\lambda}{\lambda_u} - 1 - \gamma^2\Theta^2} \quad \gamma = \frac{E}{m_e c^2}$$; Θ= observation angle (:=0) ; λ_u= undulator period

K can be calculated from this equation, which implies that one knows the electron energy ($\Delta E/E$ better than $2\mathrm{x}10^{-4}$) and the observation angle with high accuracy. As we are mainly interested in the measurement of ΔK, the third method (quadrupole kick), which compares the radiation of two undulator segments produced with the same electron bunch, will be not sensitive to the absolute electron energy or observation angle and much less sensitive to jitter effects.

The error in K for a given error in λ can be calculated from $\Delta K = \left(\frac{\delta K}{\delta\lambda}\right)\Delta\lambda$ with $\Delta\lambda \leq \rho\lambda$

Following table gives the maximal ΔK/K for FEL operation for different wavelengths:

λ	bandwidth	ρ = BW/2	K	ΔK	ΔK / K
[Angstroem]	[%]			< (1+K^2/2)/K*ρ	[1E-4]
1	0,08	0,0004	3,3	0,000781	2,4
4	0,18	0,0009	6,1	0,002893	4,7
16	0,3	0,0015	6,8	0,005321	7,8

1.3 Measurement range

In order to cover the full gap range of the undulators, the devices should be tunable in following ranges:

1) Photon energy range for SASE1 and SASE2: 3-25keV (core range 5-18keV)
2) Photon energy range for SASE3: 0.28-3keV (core range 0.4-2keV)

With a crystal monochromator we can cover the SASE3 range by observing the higher harmonics. When keeping K constant it is possible to adapt the photon energy to the optimal K-Mono range by setting the appropriate electron energy (10, 14, or 17.5 GeV).

1.4 Geometry / mechanics

The geometry is calculated for a distance to the end of the undulator of 170-250 m. In order to accept

3) Acceptance angle (incident beam) >15 µrad
(acceptance of Bragg reflections may be less)
4) Beam dimensions (width): max. ca. 10-12mm (single beam)
5) Two spatially separated beams in horizontal direction (>20-24mm horizontal acceptance)
6) Theta (observation angle): the main purpose of this device is an observation of the fundamental and odd harmonics of spontaneous radiation. So Theta should be zero. A misalignment in Theta will lead in the 4-bounce case to a significant suppression of the harmonics.
7) Stability over a measurement period (a few hours) +/- 0.1mm / 1µrad

A larger acceptance would be advantageous for lower photon energy, but due to the large distance to the undulators the crystal size would become too large. In this case it is possible to examine the 3rd, 5th, or even higher harmonics of the spontaneous radiation.

2 Requirements to other workpackages

2.1 MLC – Machine Layout Coordination

Group leaders: Winfried Decking / Torsten Limberg

For the single segment K-tuning and non-spatially resolved pairwise K-tuning it is essential to know the relative electron energy with a high accuracy and reproducibility. The precision of the absolute energy measurement can be lower.

The electron energy $\Delta E/E$ (see1.2) must be known to better than 2×10^{-4}. That means we have the same accuracy requirement for the following:

1) relative electron beam energy jitter ($<2 \times 10^{-4}$)
2) energy chirp ($<2 \times 10^{-4}$)
3) electron energy measurement resolution (relative / absolute ; bunch / averaged)

4) beam position jitter / pointing stability (angle jitter)
   minimum requirement: 30 µm / 0.5 µrad
5) electron energy scan over +/- 1.5% (or more) within 10s:
   for some applications (e.g. the steepest slope tuning method) we need a fast electron energy scan, in order to acquire a spectrum

2.2 Undulators (WP 71, Joachim Pflüger)

Quadrupole mover: the quadrupole kick method for K-determination will demand an angular kick of ca. 20 µrad (>35 µrad for lower photon energy)

2.3 DAQ / control (WP 76, Christopher Youngman)

DAQ, following signals have to be acquired and processed:

1) CCD signal or sCMOS sensor signal (area of interest selection for fast frame rate >10kHz should be foreseen if possible) including camera control
2) Photocurrent of diodes: fast, bunch resolved signal
3) Photodiode in a slow averaging mode (bunch train averaging)

Degrees of freedom to be controlled:

4) Retraction motion – in / out (motor with µm encoder)
5) 2 rotary stages for crystal rotations (piezo stage or stepper motor ; optical encoder):
   movement range 60° / resolution/repeatability better 1µrad
6) Height adjustment and chamber tilt: 2 motors ~300° movement / 2000 steps
7) Attenuator control: motorized actuator >5 positions
8) Detector movement for retraction and positioning of >3 detectors
   y-movement 75 mm, resolution/repeatability 10µm

2.4 X-ray optics (WP 73, Harald Sinn)

A beam collimator is a mandatory device before the K-Monochromator. In any case the beam collimation must allow a horizontal acceptance angle of ~ 35 µrad (from the first undulator segment).

It has to be checked if the attenuator system for the K-Mono (different from the beamline attenuator in XTD9) is part of the device, or if it can be supplied by WP73. The required attenuation is in the order of 1000 to cover the range of spontaneous radiation from only one up to all segments, and higher if used for the FEL.

2.5 Survey and Alignment (WP 32, Johannes Prenting)

Alignment with the beam:

1) Absolute accuracy +/- 0.3mm / +/- 100µrad

As it is not planned to have a remote control for a large alignment range, this level of accuracy has to be achieved during the installation and initial setup.

3 Requirements from other workpackages

3.1 X-ray optics (WP 73)

Vacuum requirements: the strictest requirements on outgassing and cleanliness come from the X-ray optics, as they have the most contamination sensitive devices. So the critical points like the use of lubricants and plastic materials will be discussed with WP73.

3.2 Undulators (WP 71, Joachim Pflüger)

For air conditioning the heat production and air resistance are important. Heat will be produced from motors outside the vacuum chamber and from electronics

1) Heat load not connected to water cooling: 200 W (rough estimation)
2) Cross section area: ~ 1 m² (for air resistance)
3) Heat load connected to water cooling: <1kW (electronics rack, in vacuum motors, photon beam absorption)

The physical requirements for the K-determination, in order to commission the undulators, are given in section 1 (requirements to the device).

4 Commissioning strategy

4.1 K- and ΔK-determination

Three different methods for K/gap-determination are taken into account (for details please refer to the cited papers). The first two methods require only an integral intensity measurement with a photodiode, so especially single segment tuning will be a fallback solution for the preferred quadrupole kick method, which requires a sensitive imager.

4.1.1 Single segment tuning / Gap tuning

The energy spectrum of one undulator segment is measured (by switching off the others), in order to determine its effective K-value, which then has to be adjusted by changing the gap accordingly. For this method an integral intensity measurement with a sensitive photodiode is sufficient. With several thousand photons per single pulse the diode signal should be big enough to measure individual pulses. The photon energy can be scanned by scanning the electron energy or the monochromator while keeping the gap fixed. Alternatively the gap can be varied at fixed observation energy for maximizing the intensity. [1: M.Tischer et al]

At LCLS currently single segments spectra are measured by scanning the electron energy in a range of +/-1%, as the monochromator energy is fixed. Each measurement point is being correlated with the electron energy measurement and normalized with an intensity measurement. In practice some hundred pulses are necessary to measure one spectrum (Si111, 4-bounce geometry at 8.13keV).

4.1.2 Steepest slope

All but two adjacent undulator segments are 'switched off' by opening the gap. Spectra of the fundamental (or a harmonic) are measured (by variation of Ee ;electron energy scan and detection as in first method) for different gap settings of one segment while the other segment is kept fixed. For the setting with the steepest slope of the high energy edge, the K-parameters match best.[2: J.Welch et al]

This method was developed at LCLS, but is currently not in use due to high noise.

4.1.3 Quadrupole kick

Also here only the radiation of two adjacent undulator segments is examined. Between the segments a quadrupole kick deflects the electron beam by up to 20 µrad. So the intensity profiles of the two segments are spatially separated and can be directly compared. When observing the radiation produced by just one electron bunch, the energy jitter effect disappears. Due to the low intensity a sensitive detector, e.g. an x-ray CCD, is mandatory. [3: T.Tanaka]

As it can be expected that the electron energy jitter within one bunch train is smaller than between bunches of different trains, it would be possible to average up to 2700 bunches of one bunch train with a high signal to noise ratio. Furthermore the requirements to DAQ would be quite relaxed (10Hz frame rate). However, this integrating mode implies availability of long bunch trains of spontaneous radiation for undulator commissioning.

But also when averaging bunches of different bunch trains with larger jitter effects, both undulator segments are affected equally. Energy chirp or jitter would broaden the averaged peaks, but as long as the center of the peak can be determined with sufficient high accuracy the relative K measurement would not deteriorate.

In the accelerator commissioning phase only single bunches with 1nC at 10Hz are available (day one scenario). An intensity calculation for this scenario is described in more detail below.

4.1.3.1 Scenario for day one

At day one we have to take into account having only single bunches with 1nC at a repetition rate of 10Hz. So in the case that the intensity from 1 bunch is not sufficient and averaging over seconds is necessary, there are higher requirements for the e-beam and detection stability. The camera for example must have a much lower dark current or readout noise.

On the other hand it can be expected that the first undulator commissioning is made at photon energies equal to or below 12.4keV, so all measurements can be performed using the Si 111 reflection. For increase of energy resolution and harmonics rejection the 4-bounce mode can be used.

One-bunch intensity (x-ray-photons)

Parameters for calculations:

- E_e = 14GeV (E_e = 10GeV)
- E_{Ph}= 12.4keV (E_{Ph}= 3keV)
- distance to first undulator segment = 450m

- distance to last undulator segment = 250m
- bunch charge = 1nC
- observation energy ~3‰ below fundamental or harmonic

Calculations of the peak intensity by Gianluca Geloni:
a) E_e = 14GeV / E_{Ph}= 12.4keV
Number of x-ray Photons per mm² per bunch after the Monochromator:

	Si(111)	Si(333)
Distance = 250m	$4x10^5$	$2x10^4$
Distance = 450m	$1.2x10^5$	$6x10^3$

b) E_e = 10GeV / E_{Ph}= 3keV / E_{obs}= 9keV (3rd harmonic)
Number of x-ray Photons per bunch after the Monochromator per mm² :

	Si(111)	Si(333)
Distance = 250m	$1.6x10^5$	$8x10^3$
Distance = 450m	$4.9x10^4$	$2.5x10^3$

(One or two-bounce bandwidth used)

Detector efficiency / SNR, yield and timing

It would be desirable if each x-ray photon on the screen could be detected, that means with a detection efficiency of one. Furthermore a large dynamic range would be helpful, but can also be increased by the use of attenuators, in order to detect the radiation from undulators at largely different positions.

a) YAG screen / lens / mirror / camera
With a yield of the YAG:Ce screen (Crytur Ltd.) of 35 Ph/keV (photon-energy) we will have 350 visible photons per 10 keV x-ray photon emitted into 4π within the crystal. As the index of refraction n_{YAG} is 1.833 there is a loss of intensity by a factor of 0.3 in our case. Therefore the optical system must have a large acceptance angle of 45° (NA=0.38) or even more, which would collect ca. 1% of the visible light from the screen [8]. That means that we will have per x-ray-photon 3.5 visible photons into the camera. So with a low-noise camera it should be possible to reach a detection efficiency close to one.
With a phosphor on a Si_3N_4 membrane the efficiency maybe could be optimized.

b) Scintillator on fiber optic / CCD
For low intensity measurements (single bunch) a CCD directly coupled to a scintillator maybe via fiber optic taper can be used. This should be more sensitive than the above mentioned setup, but a sCMOS sensor cannot be used in this case.

How many bunches do we need, in order to achieve the required accuracy with the K-measurement?

With the calculated 1-bunch intensities and the detector efficiency estimations from above we can calculate the detected x-ray photons per pixel.

For the pixel size on the scintillation screen we have to consider two effects: on one hand we need small pixels for high spatial resolution, on the other hand the pixels must be big enough in order to collect enough photons for a high signal to noise ratio (greater than 10).

Gianluca Geloni (WP72) wrote some Mathematica scripts for calculating upper and lower limits of the pixel size, depending on the number of averaged bunches, the distance to the undulator segment and the monochromator bandwidth. Results for different scenarios are shown in figures 1 to 3. Both conditions are fulfilled in the shaded area of the graphs.

Figure 1 shows the situation when averaging over 20 bunches by using the Si333 reflection with a bandwidth of 1.5×10^{-5} (single crystal or one channel-cut crystal). In order to meet both conditions the field of view (and with it the pixel size on the screen) has to be adapted to the distance to the undulator segment. When averaging 100 bunches, a pixel size between 12 and 19µm would fulfill both conditions and one could use a fixed optics.

For the calculations the bandwidth of the crystal reflections is taken from a one- or two-bounce case. The energy bandwidth of the Si111 4-bounce reflection would be 2 times smaller than the Si111 case, which can be sufficient for avoiding the Si333 reflection.

E_{ph}=12.4keV

E_e=14 GeV

Peak Flux Density in Nph/s/mm2/0.1 % BW

(from SPECTRA):

Flux=9.2×10^{10}

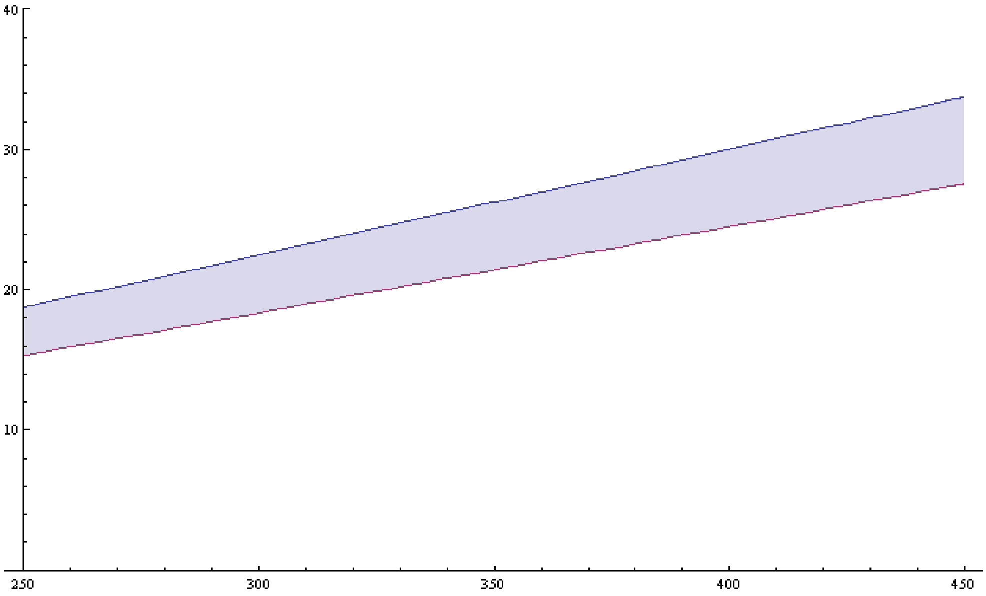

Figure 1: Pixel size versus undulator distance – 20 bunches, Si333

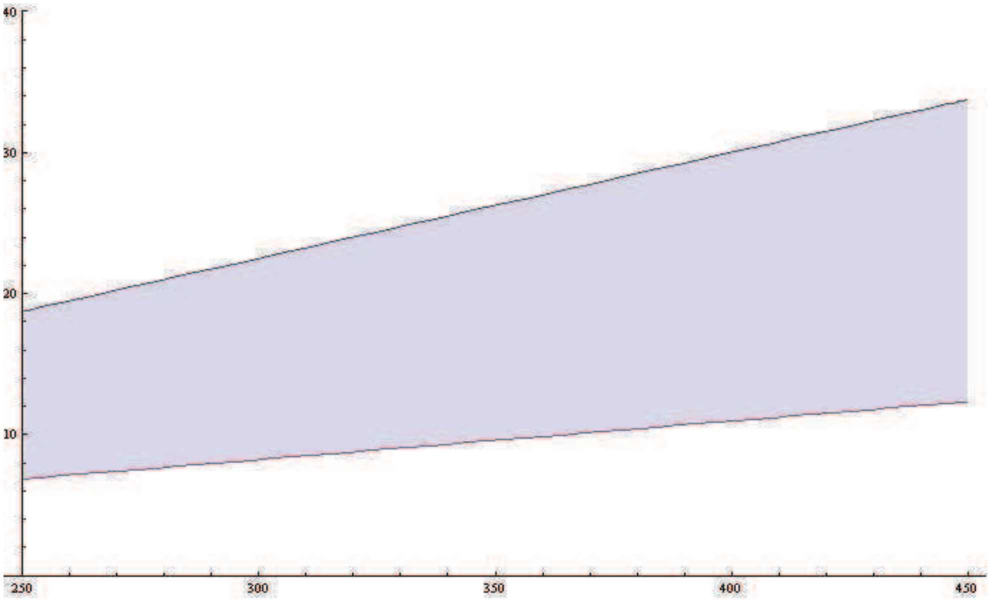

Figure 2: Pixel size versus undulator distance – 100 bunches, Si333

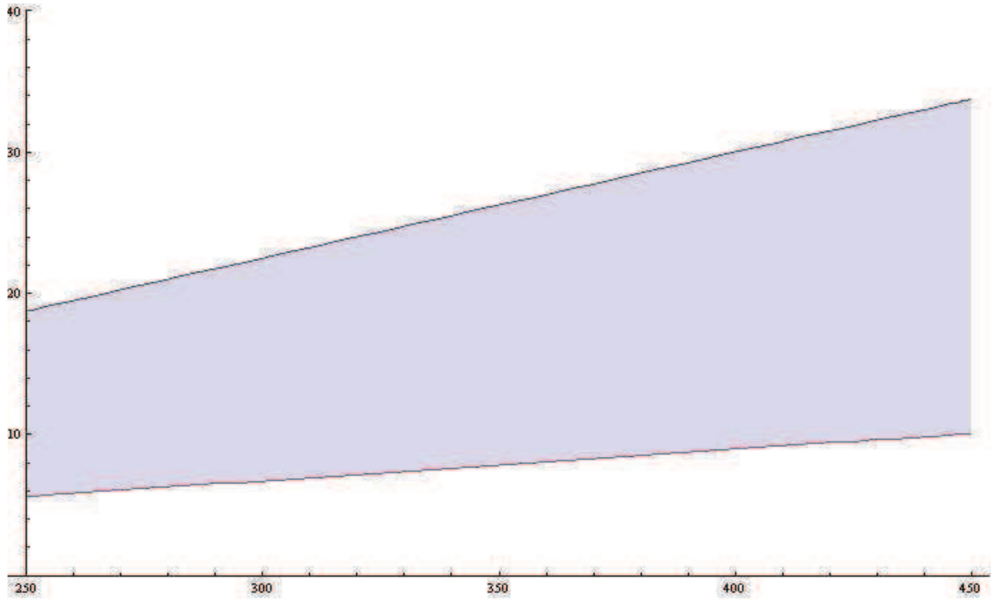

Figure 3: Pixel size versus undulator distance - 10 bunches, Si111

4.1.3.2 Conclusion

Our calculations show that at day one we will be able to use also the quadrupole kick method, even when it has a high demand for the x-ray intensity. Using the Si 111 reflection an acquisition of 10 to 100 bunches should be sufficient for one undulator segment measurement.

For the 333 reflection long averaging time has to be taken into account, which could be a problem for acquiring gap curves with a large amount of data points.

In any case we will foresee an additional photodiode detector, with which we can perform single segment tuning as it is the current standard method at LCLS. This will also require the acquisition of several hundred data points per spectrum and will be in most cases slower.

4.2 Phase adjustment

- Observe photon flux at constant energy $E_{obs}= E_{fun}$ while changing phase:
  photon flux variation by ~700 for phase advance π→2π
- Angular profile method (Tanaka):
  Close the gap of three adjacent segments and introduce a single kick between the 2nd and 3rd segment to separate the angular profiles. Vary the gap of the phase shifter between the 1st and 2nd segment to look for maximum intensity, which can be normalized by the peak intensity corresponding to the 3rd segment.

References:

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[2] T. Tanaka / Undulator Commissioning Strategy for SPRING-8 XFEL / RIKEN SPring-8 Joint Project for XFEL

[3] M. Tischer et al. / Nuclear Instruments and Methods in Physics Research A 483 (2002) 418-424

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(A tandem-lens epifluorescence macroscope)

The European XFEL Undulator Commissioning Spectrometer

Conceptual Design Review
Document 4:
Conceptual Design Description

March, 30th 2011

(Author: W. Freund)
(Review: J. Grünert)

EDMS Nr.: D00000001940181 Rev: B Ver: 3 Status: Approved Dat.: 8. Jun 2011

1 Introduction

Photon based commissioning of the European XFEL undulators will require a precise adjustment of the K-parameters of all undulator segments and phasing between these segments. The LCLS approach with a double channel-cut monochromator is a good basis for adaptations, which are necessary in order to get a conceptual design for the three SASE undulators at the European XFEL. We have to take into account the large gap setting range and wavelength ranges of 0.5 to 4Å for SASE2 and 4 to 16Å for SASE3, respectively. The spectrometer will analyze spontaneous radiation from single segments up to the full undulator length. In order to apply the spectrometer to the soft X-ray region of SASE 3, the 3rd, 5th, or even higher order harmonics will be used.

2 Technical design

2.1 Monochromator Setup

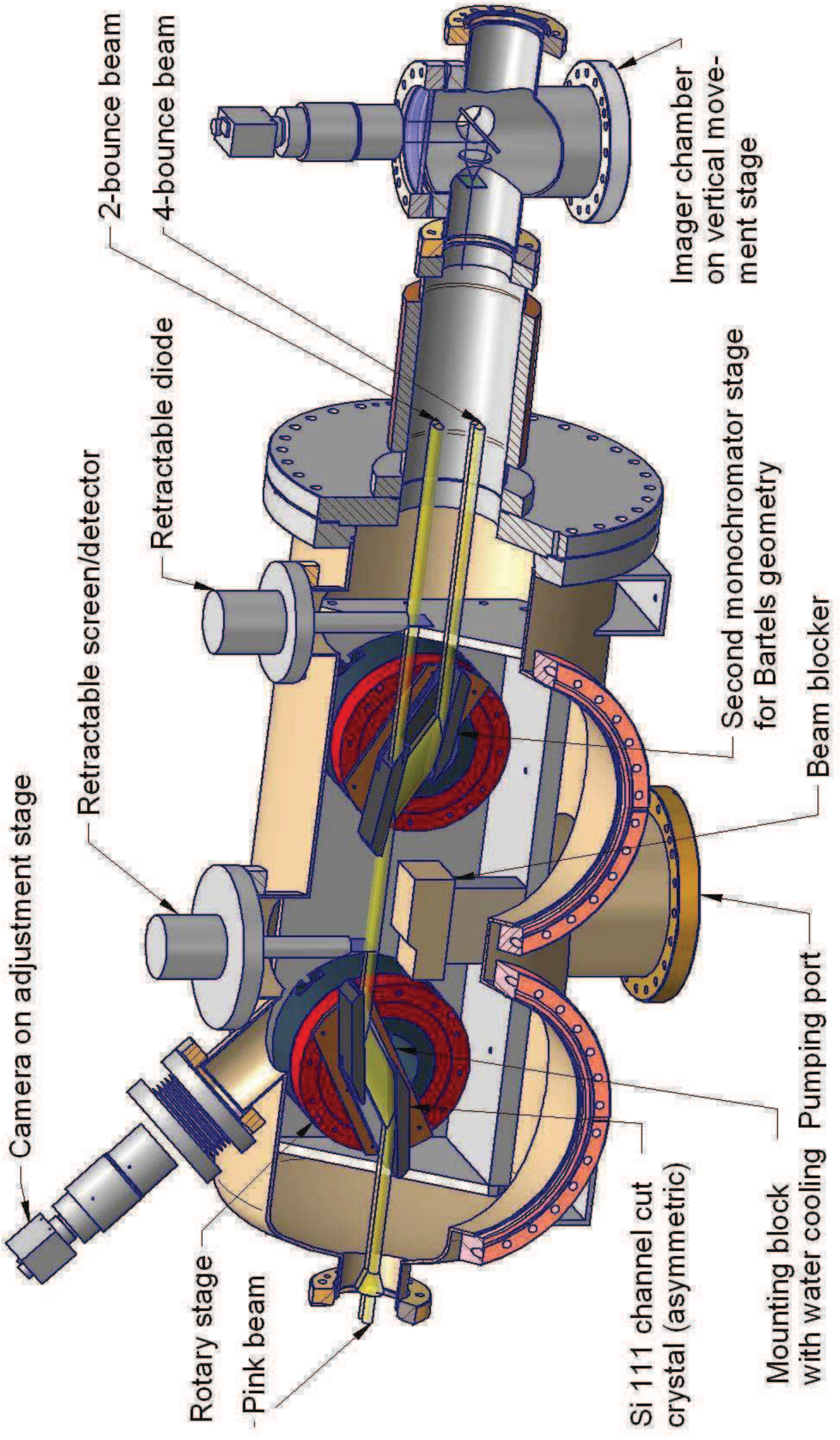
General requirements:

- Physical requirements: see document 3
- Vacuum requirements: Experiences at LCLS show contamination of mirrors with carbon layers in the nanometer range, which comes most likely from residual contamination with hydrocarbons in the vacuum system. So no outgassing of hydrocarbons, which would be cracked on sensitive optical surfaces, is allowed. That means metal vacuum seals should be preferred and the use of vacuum grease (e.g. Krytox XHT-BDZ) will be limited to the most critical bearings. Dry lubrication will be preferred if possible.
- Compact design, due to space limitations in the tunnel

Crystal stage setup:

- Channel cut Si 111 crystal.
  The crystal length will be approx. 175mm, in order to allow a large acceptance
  Optional: the use of an artificial channel cut crystal setup (APS Argonne) would increase the optical quality of the crystal surfaces.
- Indirect water cooling for temperature equalization
- Second monochromator stage for Bartels geometry with higher energy resolution and inline geometry. It could also allow slight detuning for suppression of higher harmonics.

In order to increase the angular acceptance to the use of asymmetrically cut crystals will be examined.


Camera on adjustment stage
Retractable screen/detector
Retractable diode
2-bounce beam
4-bounce beam
Imager chamber on vertical move-ment stage
Second monochromator stage for Bartels geometry
Beam blocker
Pumping port
Mounting block with water cooling
Si 111 channel cut crystal (asymmetric)
Rotary stage
Pink beam

2.2 Monochromator specifications

- Si channel cut crystals in 2- and 4-bounce geometry
- Bragg angle range: < 10° to 60°
- Energy range:2.5keV to 12.4 keV for Si111 (7.5 to 37keV for Si333)
- $\Delta E/E = 2x10^{-4}$ for Si111 ($1x10^{-5}$ for Si333)

Table 1: Bragg reflections of Si 111 (symmetric reflections)
Bragg angles in brackets are practically not useable (crystal size)

Photon energy /eV	Si 111	Si 333	Si 444
2400 / 5.2Å	55.47° 187 µrad 0.30 eV	Bragg angle Acceptance angle Energy resolution	
3100 / 4Å	39.63° 105 µrad 0.42 eV		
6200 / 2Å	18.6° 46.5 µrad 0.90eV	(73.08°) 31.5µrad 63meV	
12400 / 1Å	9.175° 21 µrad 1.77 eV	28.58° 5 µrad 0.12 eV	39.63° 5 µrad 75meV
24800 / 0.5Å	(4.57°) 10.7 µrad 3.5 eV	13.84° 2.24 µrad 0.24 eV	18.6 ° 1.9 µrad 0.15eV
40000 / 0.31Å	(2.83°) 6.6 µrad 5.74eV	(8.53°) 1.36 µrad 0.39eV	11.4° 1 µrad 0.23eV

2.3 Rotation stages

The two rotation stages can be tuned individually. Furthermore the second stage can rotate the second crystal pair out of the beam, in order to allow a 2-bounce operation of the monochomator.

- Rotation repeatability accuracy better 1µrad
- Rotation range > 60° (first stage), > 180° second stage
- crystal holder with water cooling (possibly indirect over copper braid) for temperature equalization

Following solutions will be considered:

1. UHV compatible high precision rotary stage:
   - ALIO industries AI-168R-Q: In-vacuum rotary stage with crossed roller bearings, piezo motors and optical encoder.
   - Inside vacuum rotary stage from HUBER Diffraktionstechnik GmbH & Co. KG (vacuum compatibility of motor to be checked).
2. Differentially pumped rotary feedthrough for coarse rotation, motorization and bearing on atmospheric side, flexible link rotary stage for fine adjustment and encoder inside vacuum (possible technical cooperation with HZB, Tino Nöll)
3. Sine bar drive with linear motor inside vacuum or linear feedthrough.

Following standard solutions will currently not be considered, as ferrofluidic seals are not UHV compatible and this solution is more expensive:

> Rotary drive out of vacuum: ferrofluidic rotary feedthrough with motorization and bearing on atmospheric side (solution like FMB Oxford monochromator)
> (outgassing of ferrofluidic liquid to be checked !)

2.4 Attenuation systems

The photon beamline attenuators from WP73 (maybe even downstream from the K-Monochromator) would have a too small acceptance. So an additional attenuator system is needed. This system does not need to withstand the full FEL beam. It will bring attenuation foils into the beam before the monochromator, which will be mounted on a linear slide or a wheel in a separate chamber. Especially lower harmonics will be suppressed, which would be useful for the observation of higher harmonics.

Additional foils will also be chosen for different absorption edges (e.g. Nickel foil with an absorption edge at 8.333keV) for energy calibration purposes.

This chamber could be developed in house, but it is also possible to purchase a commercial system (e.g. Bruker).

2.5 Detection

All detectors will be vertically movable, in order to allow the detection of the direct beam and inline beam in 4-bounce geometry, as well as the parallel offset beam of the 2-bounce case. In order to be able to increase the energy resolution in case of the 2-bounce setup a movable and adjustable exit slit will be added.

- Retractable screen and/or detector
- Screen and CCD (or sCMOS / EMCCD) for imaging high or time integrated intensity
  - resolution between 10 and 20 μm (on screen)
  - low noise sensor for low intensity (spontaneous radiation of 1 segment)
  - large dynamic range for FEL
  - scintillator screen (e.g. YAG:Ce)
  - optical system: e.g. taper or tandem lens with mirror [8]
    camera must be protected from radiation, e.g. with mirror or lead glass disc

- Diode detector for integral measurements:
  - large enough to accept full spot (~ 12mm)
  - fast: single-shot capability
  - should accept also 3rd harmonic
- Option: direct imaging X-ray CCD for low intensity and single bunch imaging sensitive and expensive device, so it will be not included in the initial setup.
  It will be checked if the detection chamber can be designed in order to accept an x-ray CCD.

Even when it is planned to have some detection inside the monochromator chamber, an additional detection chamber is planned. This chamber will be adapted to the special geometrical requirements of the detectors. It will allow a shorter distance between scintillator screen and camera as well as observing the direct beam.

2.6 Retraction mechanism

As this device is not an online device, it has to be fully retractable from the direct beam. The detectors have to be movable for the 2-bounce case and will be covered by the detector chamber design. Following options can be considered:

1. The monochromator chassis can be retracted by ca. 25mm inside the chamber (monochromator can keep the wavelength adjustment)
2. The whole chamber can be moved on a linear bearing outside the vacuum. Here the detectors inside the K-Mono chamber could not be used in the direct beam.
3. Rotating the crystals with their rotary stages out of the beam. The beam blocker can then be retracted by a simple pneumatic device. For this concept the rotary stages need a big rotary range with a high accuracy in the repeatability.

Option 3 would be in principle sufficient for a retraction mechanism. But in case of a failure of one of three drive mechanisms (2 rotary stages and the beam blocker) the device would block the whole beamline. So one of options 1 or 2 should be realized, in order to get a built-in redundancy.

2.7 Position in the beamline

Requirements to the position in the beamline:

a) close to the undulator
b) behind the separation of the electron beam
c) behind solid state attenuation
d) behind beam collimation/apertures (power slits)

SASE 1:

In case of SASE 1 the undulator is placed in tunnel XTD2, as well as the beam separation. Positions: XTD2 Room 13, ~240 m behind undulator end

Disadvantage: additional effort for radiation shielding due to small distance to dipole

magnet of beam separation and close distance to electron beamline
Advantage: closest possible distance to undulator.

SASE 2 (in tunnel XTD1):

Position: XTD1 Room 10 or 11: additional effort for radiation shielding due to small distance to dipole magnet of beam separation

SASE 3 (XTD4)

Position: in XTD10 behind the beam dump

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(A tandem-lens epifluorescence macroscope)