MOPC12

European XFEL

XFEL photon diagnostics – overview of cornerstone methods

Jan Grünert, Wolfgang Freund

Work Package X-Ray Photon Diagnostics (WP74), European XFEL, DESY, Hamburg, Germany jan.gruenert@xfel.eu

Introduction

We present considerations for photon diagnostics devices for the European XFEL in view of the FEL beam parameters. This poster is based on the discussions at a workshop dedicated to x-ray photon diagnostics in Ryn/Poland in February 2010. The methods are grouped under the three main photon beam characteristics - spectral, temporal and spatial properties, where the latter contains also wavefront and coherence properties. Finally, a short report of two recent diagnostics experiments is given.

* www.xfel.eu/events/workshops/2010/x_ray_diagnostics_and_scientific_application_workshop/

International workshop on X-ray diagnostics and scientific application of the European XFEL

- 14-17 February 2010 in Ryn / Poland
- jointly organized by European XFEL and Andrzej Soltan Institute for Nuclear Studies (Świerk, Poland); 62 participants
- three Work Groups for the three groups of beam properties, chaired by G.Geloni + M.Messerschmidt (WG1), J.Grünert + M.Yabashi (WG2), and M.Meyer + H.Zacharias (WG3); we highly acknowledge their input
- all presentations and full references on www.xfel.eu

Measurement of Spectral Properties

	Purpose of spectral measurement	Required resolution in 1-3keV range	in 6-12keV range	comments
A	Monitor central photon energy (center-of-mass)	3E-04	1E-04	FEL-Bandwidth sampled by 10 points
B	Determine pulse duration – spike width	6E-6	4E-7	average rms frequency spike widths
C	Beam position (center-of-mass of profile)	10% of beam diameter ~1-3mm @ z=300m	10% of beam diameter ~1mm @ z=1000m	
D	Bandwidth	3E-04	1E-04	BW~ρ (FEL-parameter) sampled by 10 points
E	Undulator commissioning	1.5E-04	4E-05	condition: $\Delta\lambda/\lambda<\rho$ (and sampled by 10 points)
F	Spatial / transverse distribution of spectral modes			
G	Higher harmonics content (intensity ratios)	0.1% level	0.1% level	1st harmonic is at 1% intensity, 3rd harmonic at 0.1%
H	Polarization (accuracy of linear pol., degree of helical pol.)	1% level	1% level	user requirement
I	Calibration of monochromator	t.b.d.	t.b.d.	depends on monochromator
J	Compare against other spectral techniques	n.a.	n.a.	
K	Transverse coherence		1E-8	see Yabashi et al., PRA 69, 023813 (2004)

Which technique for which purpose ?

Destructive methods

1. crystal spectrometer
   a) dispersive (A,B,D,I,K)
   b) non-dispersive = monochromator (E/F, G)
2. grating spectrometer (A,B,D,E/F)
3. refraction with prism (A,D,G)
4. dispersive XRRS (A,B,D,I)
5. Energy calibration by absorption edge (foil/wedge in beam+scan electron energy) (A,G)

Online measurements = non-destructive measurements

1. gas based – photoionization (A,B,C,D,G,H,I)
2. beamsplitter + destructive measurement
3. for soft x-rays: grating in first order (A,B,D,E/F)

The letters in brackets correspond to the purposes in the table

see also poster THPC03

WG II (chairs J.Grünert + M.Yabashi)

Table 1: Required resolutions in the energy ranges 1-3keV and 6-12keV for the spectroscopic measurement purposes (A,C,G,H are required shot-to-shot, while E,F,I could be integral measurements)

Measurement of Temporal Properties

WG III (chairs M.Meyer + H.Zacharias)

Parameters of interest and methods

- **pulse duration** (few fs and ~100fs mode, average and single-shot) and **shape** (per shot)
  - saturated K and L shell absorption (in Al: *Nagler et al.*) → two-pulse split&delay unit ("autocorrelator")
  - Streaking x-rays with IR generated from the same electron bunch or with a ~10 µJ far-IR pulse from a laser source synchronized to the electron bunch by difference frequency mixing (*Yeh et al./ Reimann*)
  - optical radiation from a 2nd undulator, possibly frequency doubled (method probably not suited)
- **X-ray pulse arrival time** relative to optical laser pulse (precision better than 10fs)
  - X-ray induced changes in the electronic structure of solid-state materials: changes in reflectivity (*Gahl et al.*) and transmission (*Sokolowski-Tinten*)
  - Side-band generation (*Radcliffe et al.*) and two-color cross-correlation (for longer XFEL pulses)
  - Phonon driven structural phase transitions (photoinduced metal-to-insulator transition, Beaud et al)
  - Transverse electro-optic sampling (*Azima et al.*) } measures electron bunch arrival time
  - Phase shift in RF cavities } measures electron bunch arrival time
- **temporal coherence** (expected coherence times 0.2 fs @12 keV and 1.4 fs @ 250 eV)
  - device: two-pulse split and delay unit, could provide info about pulse shape (*Mitzner et al., Sobierajski*): sub-pulses cross correlate even in a linear correlation, yields at a certain delay time relative to zero delay a local maximum in the visibility, even when the sub-pulses have no fixed pulse-to-pulse phase relationship
- single-shot **spectral distribution** (relevant to non-linear resonant processes)
  - provides only a lower bound of the pulse duration, because the chirp of the x-ray pulses is unknown

Spatial profiles, wavefront, coherence

WG I (chairs G.Geloni +M.Messerschmidt)

Parameters of interest

- spatial profile: source size, position and stability, and the focus
- coherence: transverse coherence length, degree of coherence (60-90% at saturation), and the number of coherent modes

Methods

- ablation in the focus: PMMA for XUV, for hard x-rays maybe high-Z amorphous non-conducting materials (proposal by *Juha*) An AFM should be close to the experiment
- Source Imaging, e.g. by CRL lenses (*ESRF*) close to the undulator → micron accuracy of the source location

Wavefront

- adjusting the micro-focus of e.g. a KB mirror system (traditional fluorescence screens and knife edge scans fail, but diamond as fluorescent material might work)
- Grating or Hartmann Interferometer: required resolution should be ~λ/20 PV (now λ/10 for VUV)
- can also characterize transverse coherence (*Weitkamp*)

Coherence

- classical double-slit interferometric
- Nanointerferometry based on Si Refractive Bilenses (*Snigirev*)
- boron or carbon fibers, or a collection of scattering spheres in Brownian motion (*Giglio*)

For full references and all presentations, please refer to www.xfel.eu/events/workshops/2010/x_ray_diagnostics_and_scientific_application_workshop/

Recent experiments

Diamond intensity and position monitor

- Test of two diamond detectors with hard x-ray SR beam to
  - develop *transmissive* zero-intensity-monitor (I0) and position-sensitive detector (PSD) for hard x-rays
  - understand applicability range of diamond detectors
- Environment (June 2010 beamtime with Ch. Bressler et al. at PSI)
  - PSI – SLS – µXAS-beamline X05, behind monochromator, w/ & w/o KB mirrors
  - Ring current: (50mA) 400mA → 4.8E12 photons/s at 7.05keV

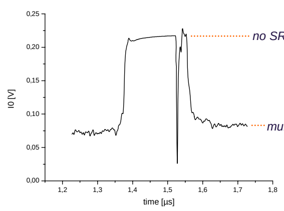


Figure 1: I0-signal nicely resolving single "cam-shaft" (with 200MHz bandwidth preamplifier)

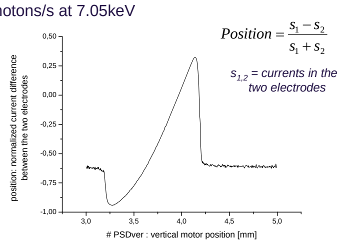
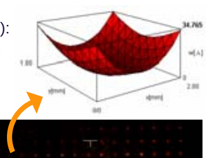


Figure 2: PSD-signal / norm. current difference in the two electrodes during motor movement

Hard x-ray Wavefront Measurements

- Test of Hartmann Plate Wavefront Sensor with hard x-ray SR beam to assess spectral applicability range of Hartmann scheme
- Environment (July 2010 beamtime with B.Flöter / LLG at DESY):
  - PETRA3 – beamline P10, behind monochromator, no mirrors
  - Ring current: ~80mA → ~1E13 photons/s at 7.1keV
  - reference image by using slits as diffracting apertures



PCO4000

variable distance: S = 30cm to 2.5m

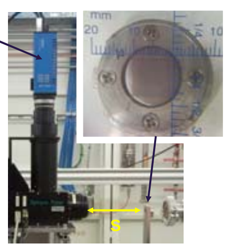


Figure 3: central part of setup with 2 cameras (LLG sensor is behind PCO) and Hartmann plate

Figure 4: example of LLG image: the diffracted beam can cover large enough area