Start-up Boundary Conditions for the SCS Instrument at the European XFEL

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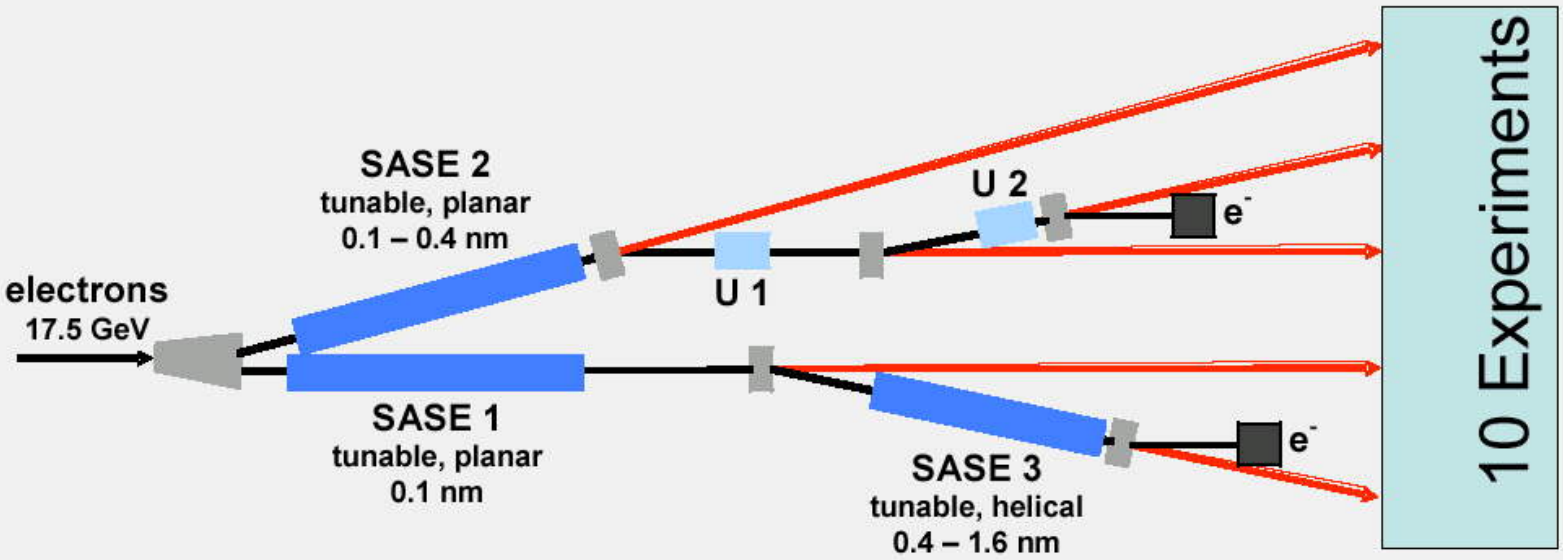
Undulators, „Technical Design Report“ (TDR 2006)

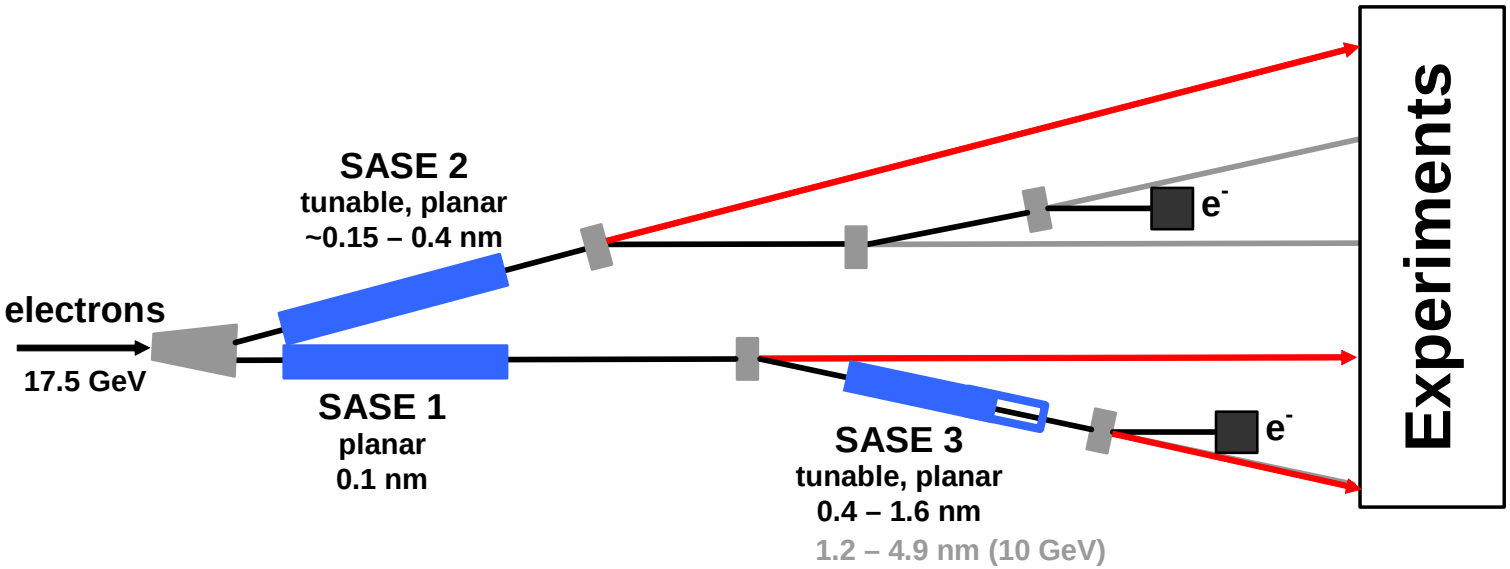


Baseline design

- 2 SASE FELs for hard x-ray FEL radiation
- 1 SASE FEL for soft/medium x-ray FEL radiation
- 2 undulators for spontaneously emitted synchrotron radiation (optionally replace U 1 by additional SASE FEL for soft X-ray range)
- Use spent beam for soft x-ray FEL and spontaneous radiation undulators

Undulators, Start-up Scenario

- Concentrate on SASE radiation
  - provide as large as possible photon energy range
  - for soft X-rays start with linear polarization
  - enable use of harm./spont. emission in SASE beamlines



Properties of XFEL Radiation

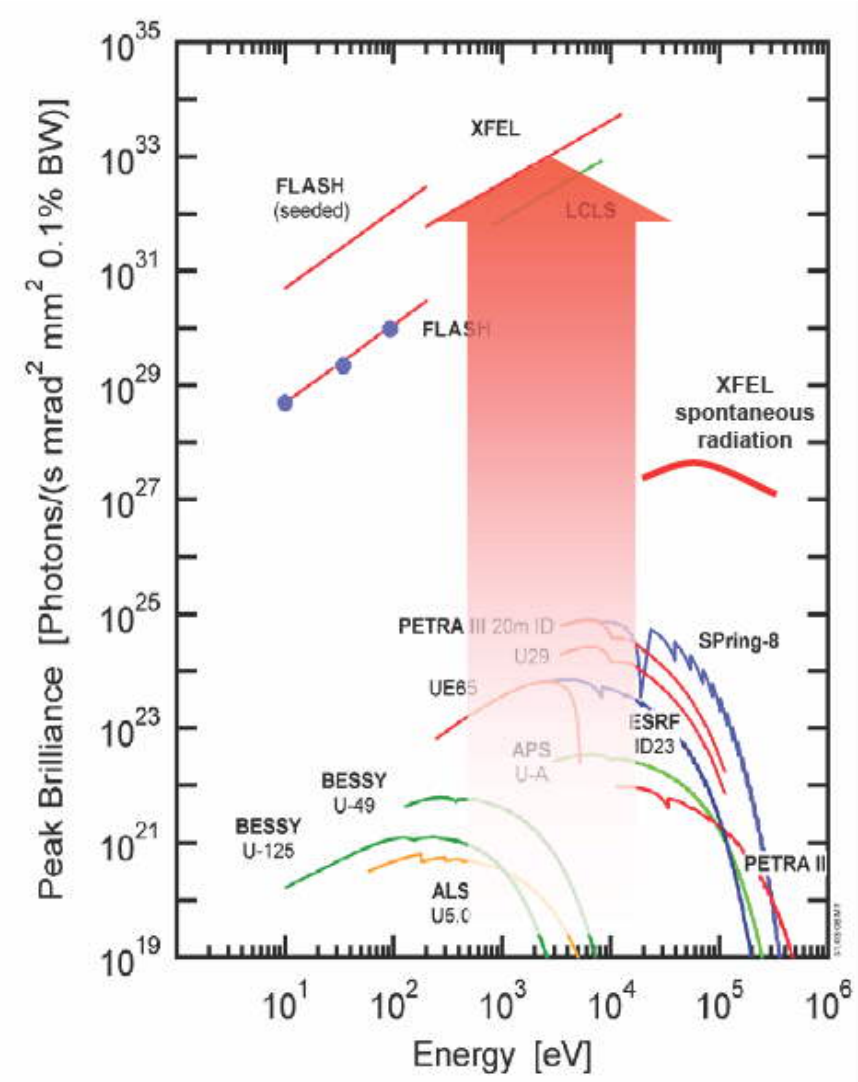
- energy range 0.2-12.4 keV

- pulse duration 100 fs

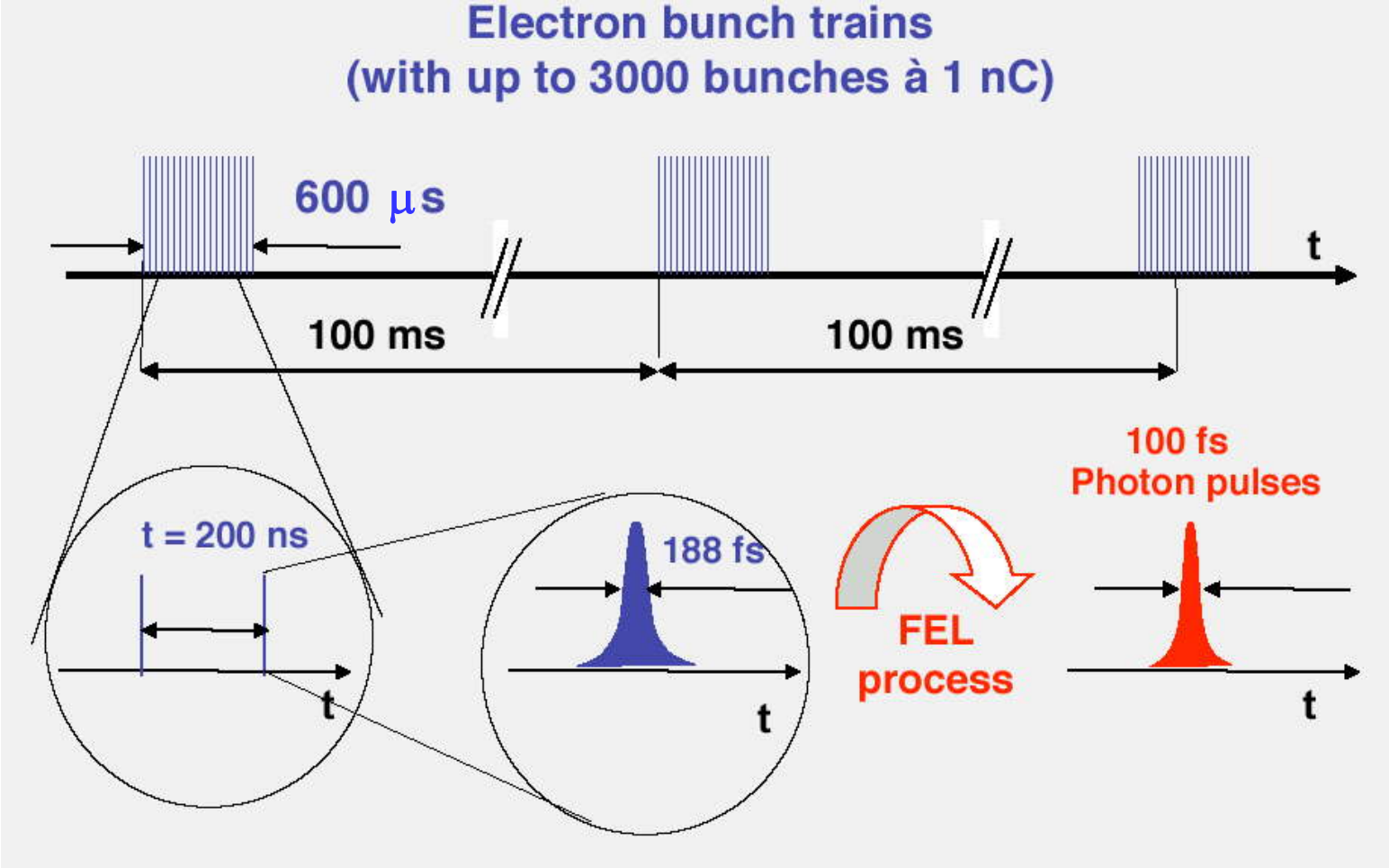
- pulse intensities 10^{12}-10^{14} ph

- peak brilliance (*PB*)
10^{32}-10^{33} ph/(s mrad^2 mm^2 0.1% BW)

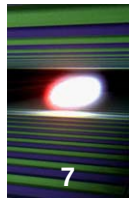
$$PB = \frac{Number\ of\ photons}{\Delta_x \Delta_{x'} \Delta_y \Delta_{y'} \times bandwidth \times \Delta_t}$$



Time Structure



Undulator Parameters

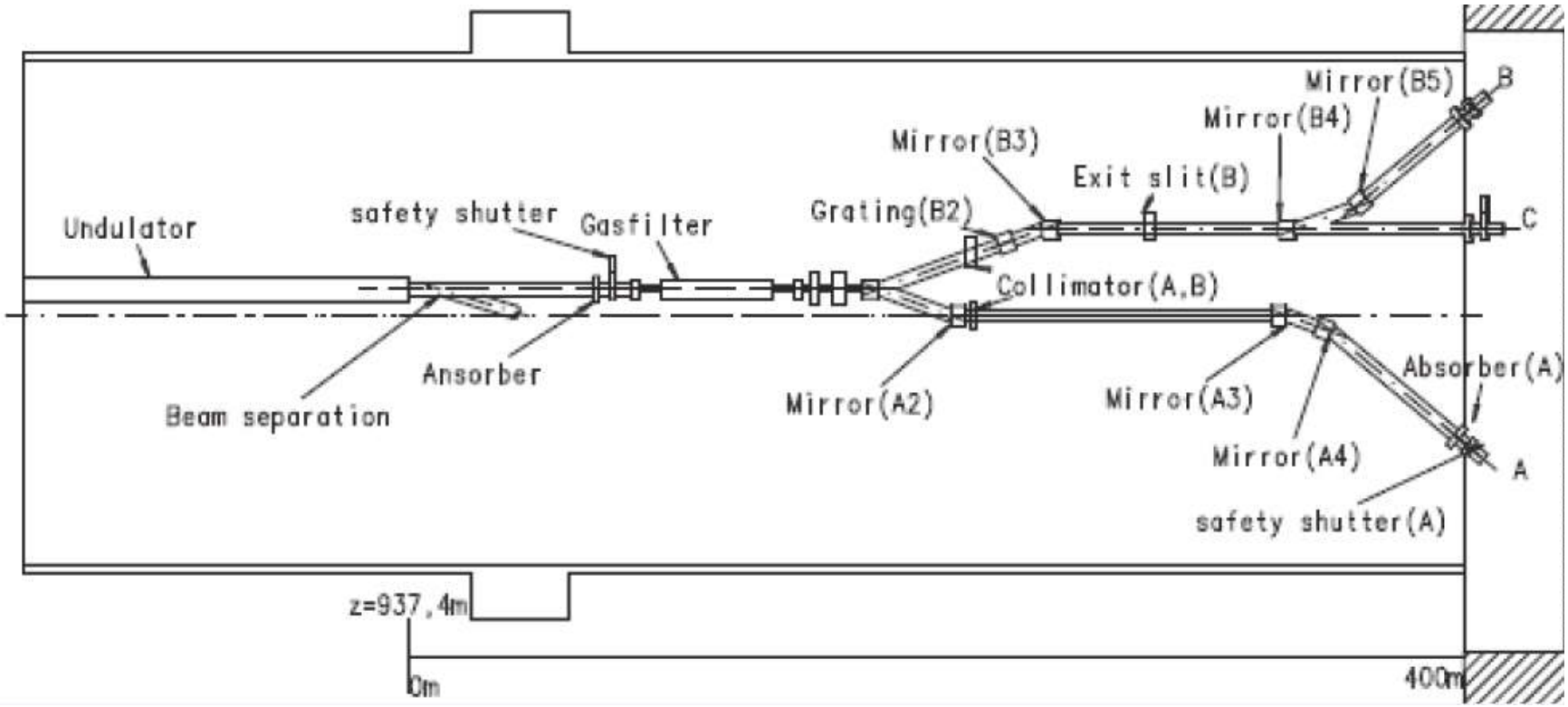


Parameter	Unit	SASE 1	SASE 2		SASE 3		
Electron energy	GeV	17.5	17.5	17.5	17.5	17.5	10.0**
Wavelength	nm	0.1	0.1	0.4	0.4	1.6	6.4
Photon energy	keV	12.4	12.4	3.1	3.1	0.8	0.2
Peak power	GW	20	20	80	80	130	135
Average power*	W	65	65	260	260	420	580
Photon beam size (FWHM)	μm	70	85	55	60	70	95
Photon beam divergence (FWHM)	μrad	1	0.84	3.4	3.4	11.4	27
Coherence time	fs	0.2	0.22	0.38	0.34	0.88	1.9
Spectral bandwidth	%	0.08	0.08	0.18	0.2	0.3	0.73
Pulse duration	fs	100	100	100	100	100	100
Photons per pulse	#	10^{12}	10^{12}	1.6×10^{13}	1.6×10^{13}	1.0×10^{14}	4.3×10^{14}
Average flux	#/s	3.3×10^{16}	3.3×10^{16}	5.2×10^{17}	5.2×10^{17}	3.4×10^{18}	1.4×10^{19}
Peak brilliance	B	5.0×10^{33}	5.0×10^{33}	2.2×10^{33}	2.0×10^{33}	5.0×10^{32}	0.6×10^{32}
Average brilliance*	B	1.6×10^{25}	1.6×10^{25}	7.1×10^{24}	6.4×10^{24}	1.6×10^{24}	2.0×10^{23}

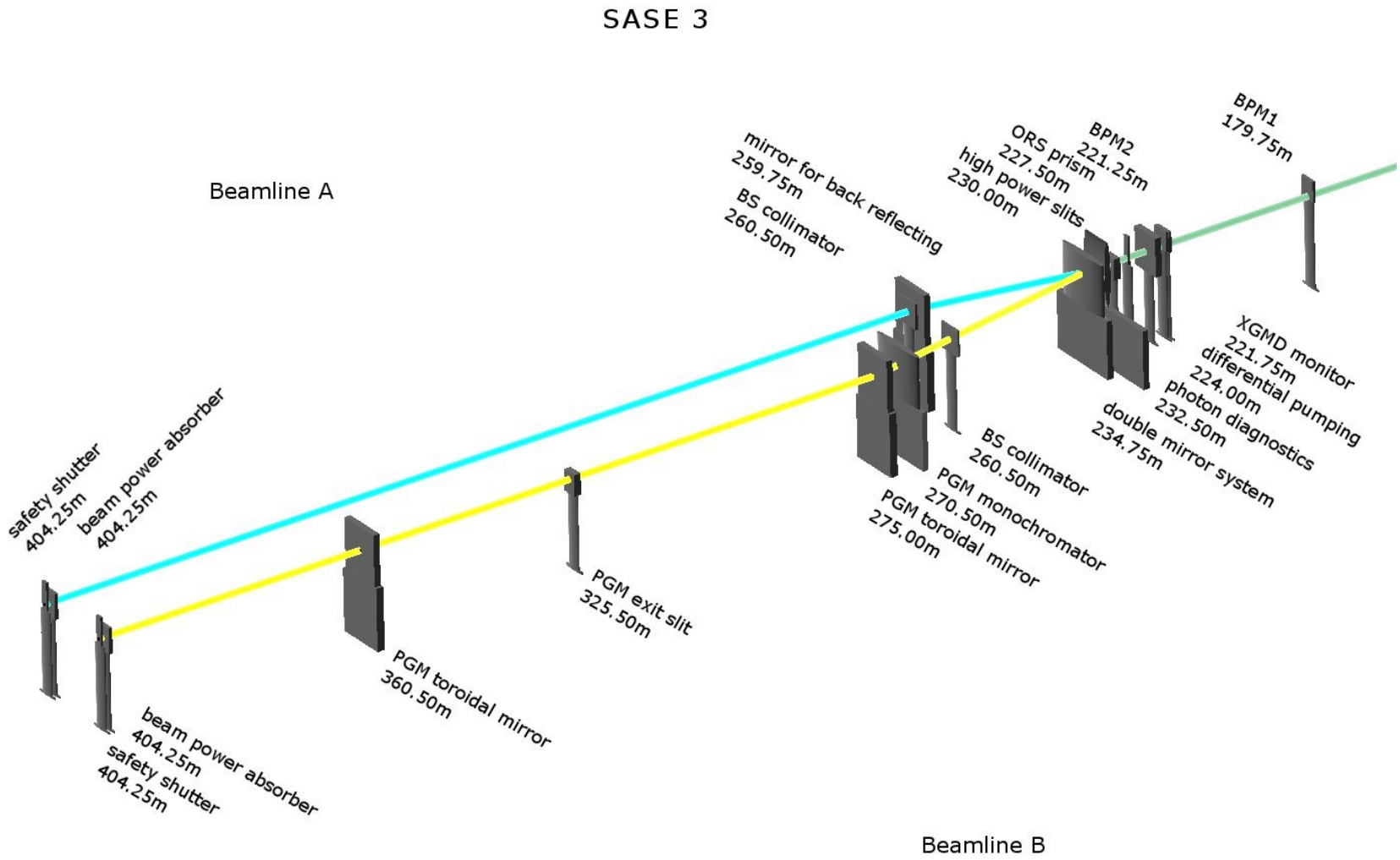
SASE 3 Photon Beamlines (TDR)

Beamline with 2 branches

- preservation of coherence (wavefront)
- full bandwidth (10^{-2} -10^{-3}) & monochromatization (10^{-4})
- two separate beam transports



SASE 3 Photon Beamlines (Start-up)



Selection of First Instruments (Start-up)

Soft X-rays — Hard X-rays

Instrument	Brief description of the instrument
SPB	Ultrafast Coherent Diffraction Imaging of Single Particles, Clusters, and Biomolecules – **Structure determination of single particles: atomic clusters, bio-molecules, virus particles, cells.**
MID	Materials Imaging & Dynamics **–Structure determination of nano-devices and dynamics at the nanoscale.**
FDE	Femtosecond Diffraction Experiments – **Time-resolved investigations of the dynamics of solids, liquids, gases**
HED	High Energy Density Matter – **Investigation of matter under extreme conditions using hard x-ray FEL radiation, e.g. probing dense plasmas.**
SQS	Small Quantum Systems – **Investigation of atoms, ions, molecules and clusters in intense fields and non-linear phenomena.**
SCS	Soft X-ray Spectroscopy & Coherent Scattering – **Atomic, electronic structure and dynamics of nano-systems and of non-reproducible biological objects using soft X-rays.**

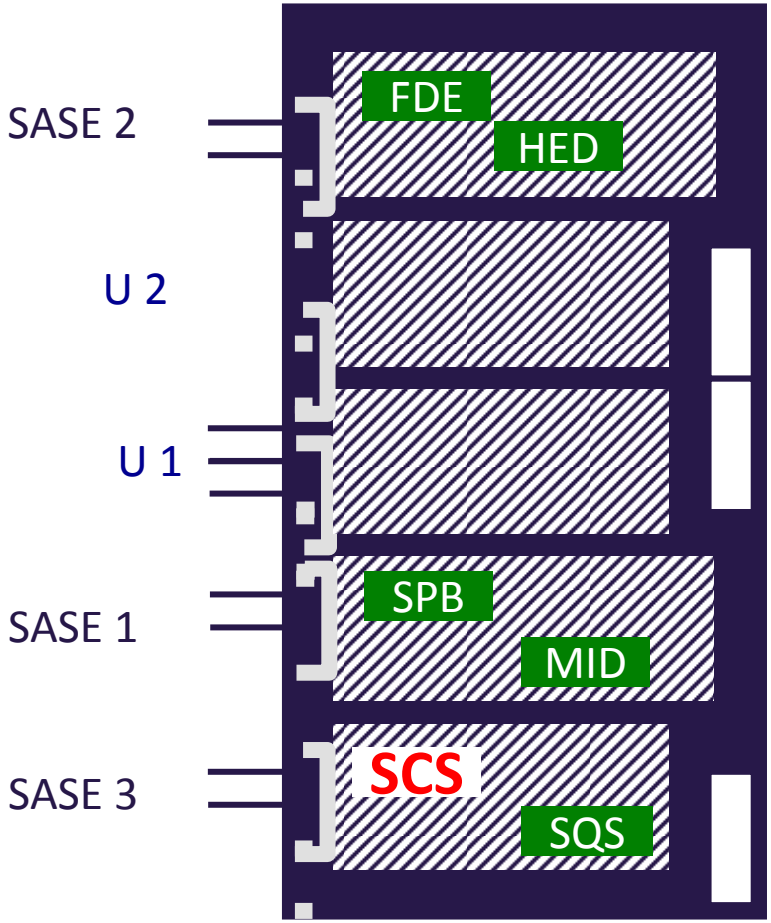
SASE 3 Instruments (SCS & SQS)

Possibility of beam distribution in 2 branches:

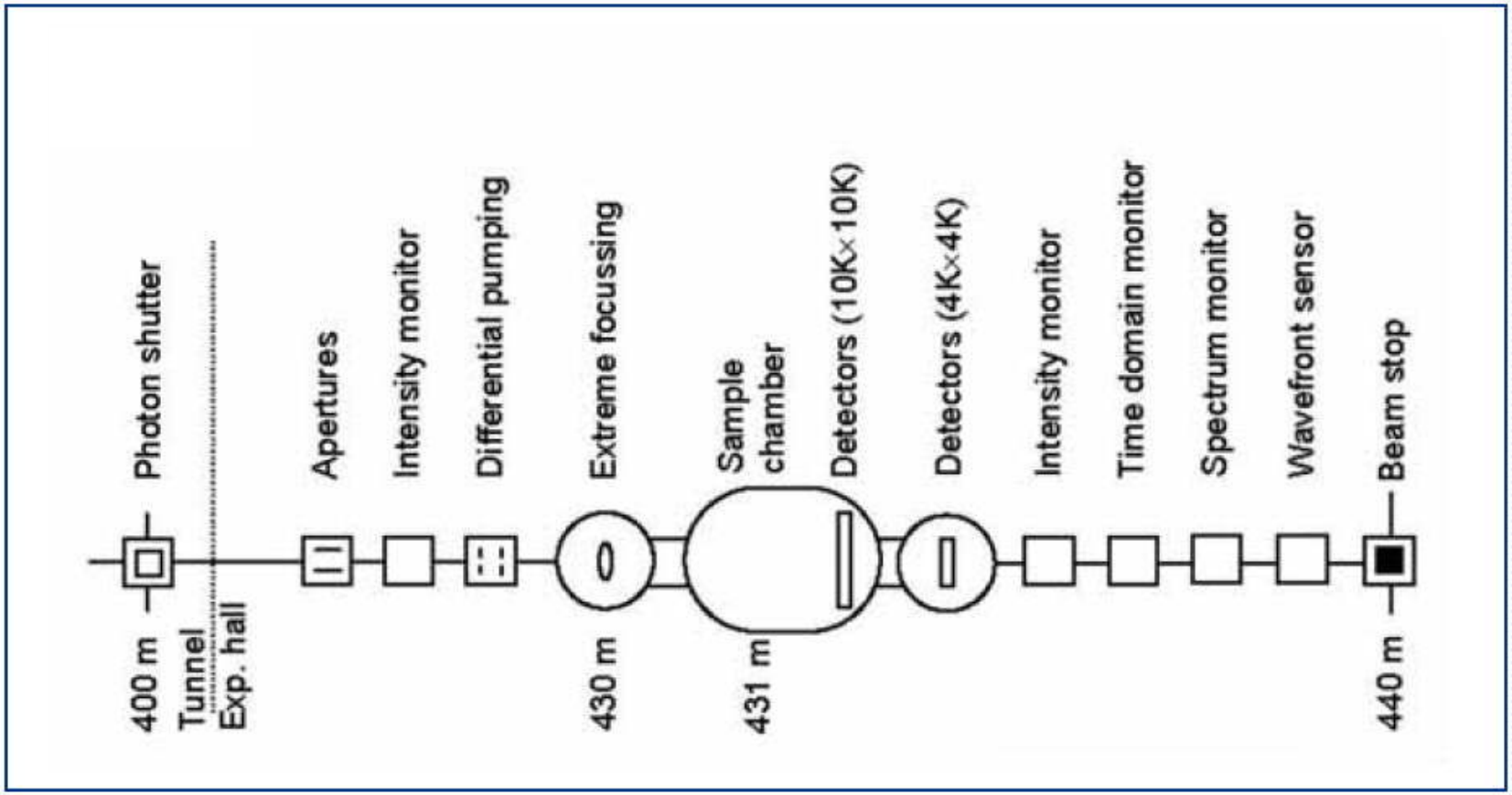
- high flux branch
- high resolution branch

Sharing with SQS instrument of:

- beamline parameters
- space and infrastructure



SCS Instrument: Imaging, Layout (TDR)



Variation in distances between optics-sample-detector is foreseen.

SCS Instrument: Imaging, Parameters (TDR)

Item	Purpose	Specification
Slits/apertures	Beam definition, beam halo cleaning	0.25 μm accuracy, 1 μm repeatability
Intensity monitor	Measurement of incident photon flux	Transmissive (<5% absorption), single pulse measurement, relative accuracy $<10^{-3}$
Differential pumping	Separation of beamline and experiments vacuum	10^4 steps for all elements
Focusing optics	Extreme focusing for 0.28-1.0 keV	0.1 μrad angular stability
Sample chamber	Sample positioning and orientation, systems to verify sample alignment, provision of sample preparation	x-y-z move (0.25/1 μm), two rotations (0.25/1 mdeg), optical microscope, UHV conditions
Detector	Measurement of forward scatting in imaging experiments	2-D, 4K×4K pixels, 10×10 μm pixel size, central hole or beamstop
Detector	Measurement of diffraction for CXDI experiments	2-D, 10K×10K pixels, 0.1×0.1 $mrad^2$ pixel res.
Intensity monitor	Measurement of transmitted photon flux	Transmissive (<5% absorption), single pulse measurement, relative accuracy $<10^{-3}$
Spectral monitor	Measurement of mean energy, bandwidth, and harmonic content	Single pulse measurement, relative accuracy $<10^{-3}$
Spatial monitor	Measurement of spatial distribution, focus size	Single pulse measurement

Rough Time Schedule

2008+ Formation of user groups for first instruments

- Requirements for beam transport
- Scientific scope and layout instruments
- Infrastructure needs for instruments

2009+ Establish and review conceptual designs

- X-ray Optics & Beam Transport
- Scientific Instruments

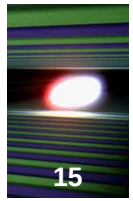
2010+ Establish and review technical designs

2011+ Construction and commissioning

2014 Involve Users in early experimental program

2015 Start full operation of most instruments

Points of Discussion at Working Group Sessions



Photon beam parameters:

- photon energy (down to 800 eV, 200 eV)
- need of high resolution ($\Delta E/E < 10^{-3}$)
- pulse duration (100 fs, shorter)
- synchronization (10 fs)
- repetition rate (5 MHz, 1 MHz, 10 Hz)
- light polarization (linear, circular)
- beam size (100 μm, 10 μm, 1 μm, < 1 μm)

Points of Discussion at WG Sessions: Instrumentation

Endstation(s)

- flexible multipurpose endstation (SCS)
- separate endstation for each WG (SCS1, SCS2, SCS3 …)
- financing issues for equipment provided by users

Photon diagnostics

- photon flux; spectral & temporal distribution; focus size; polarization; synchronization

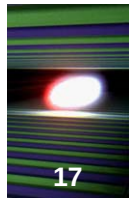
Detector requirements

- photon detectors (energy-, angle-, time-resolved)
- particle detectors (space-, energy-, angle-, time-resolved, pixel size, capacity)

Optical lasers

- wave length; pulse energy and duration; repetition rate

Output of the Working Groups



A. Science:

- identify scientific cases for the instrument

B. Technical Issues:

- SASE generation and beam delivery
- SCS instrumentation requirements
- needs for additional instrumentation, sample environment

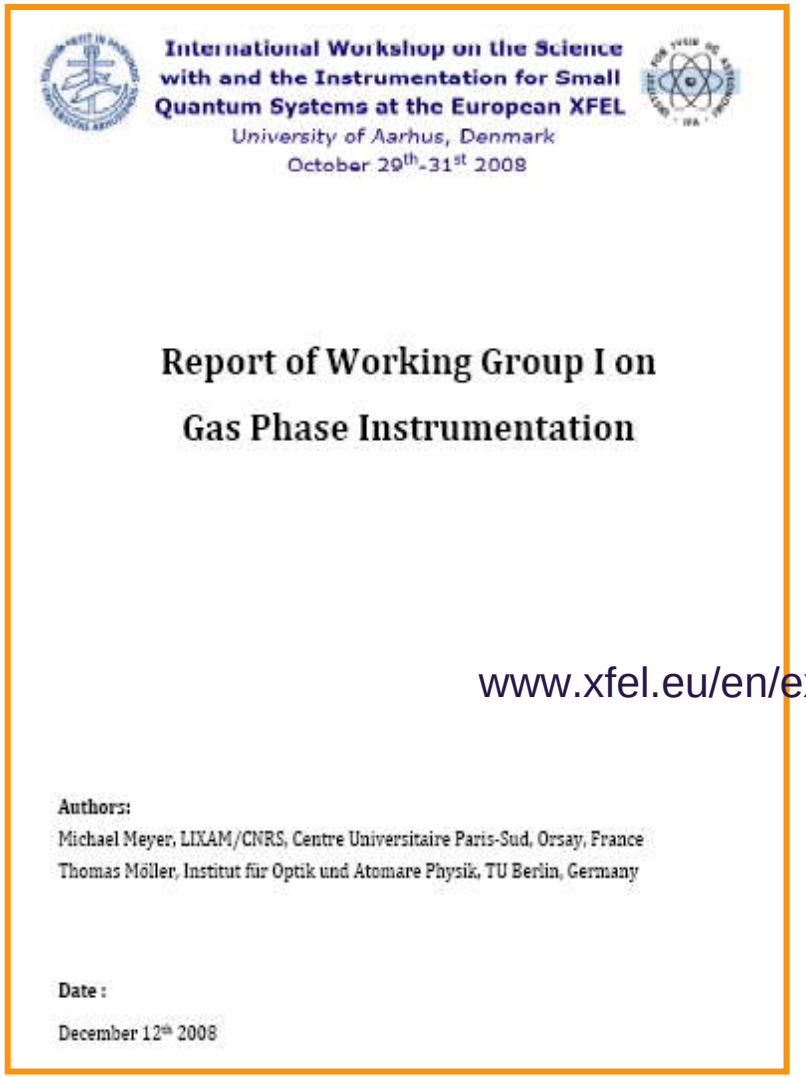
C. User Community:

- establish SCS user community(ies) group(s) [list, emails, future meetings]
- define process to resolve open questions (applications for user provided instrumentation)

D. Brief Report:

- summarizing WG discussions
- suggested instrumentation
- proposed activities to establish missing instrumentation

Output of the SQS Working Groups: Reports



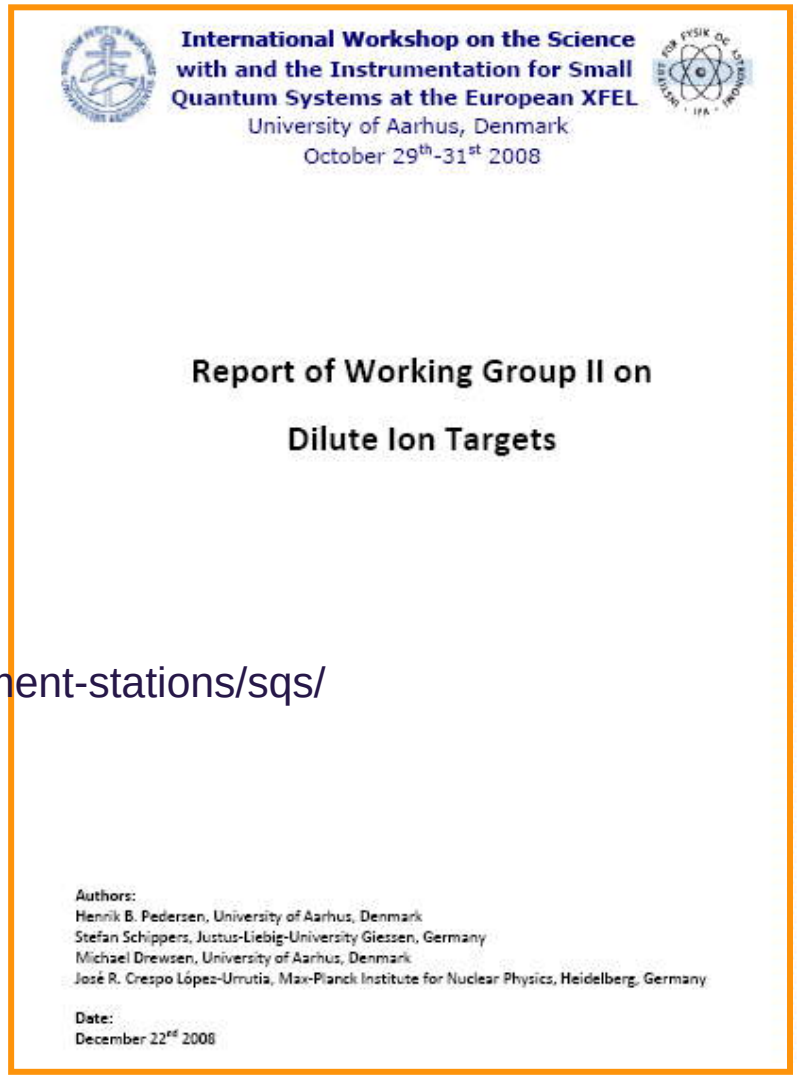
International Workshop on the Science with and the Instrumentation for Small Quantum Systems at the European XFEL
University of Aarhus, Denmark
October 29th-31st 2008

Report of Working Group I on

Gas Phase Instrumentation

Authors:
Michael Meyer, LIXAM/CNRS, Centre Universitaire Paris-Sud, Orsay, France
Thomas Möller, Institut für Optik und Atomare Physik, TU Berlin, Germany

Date :
December 12th 2008



International Workshop on the Science with and the Instrumentation for Small Quantum Systems at the European XFEL
University of Aarhus, Denmark
October 29th-31st 2008

Report of Working Group II on

Dilute Ion Targets

Authors:
Henrik B. Pedersen, University of Aarhus, Denmark
Stefan Schippers, Justus-Liebig-University Giessen, Germany
Michael Drewsen, University of Aarhus, Denmark
José R. Crespo López-Urrutia, Max-Planck Institute for Nuclear Physics, Heidelberg, Germany

Date:
December 22nd 2008

www.xfel.eu/en/experiment-stations/sqs/

Conclusions

European XFEL invites user community for close interaction aiming at elaboration of scientific programs dealing with different instrumentation

The Soft X-Ray Spectroscopy and Coherent Scattering (SCS) instrument is undergoing review. User's input is of highest importance in this process

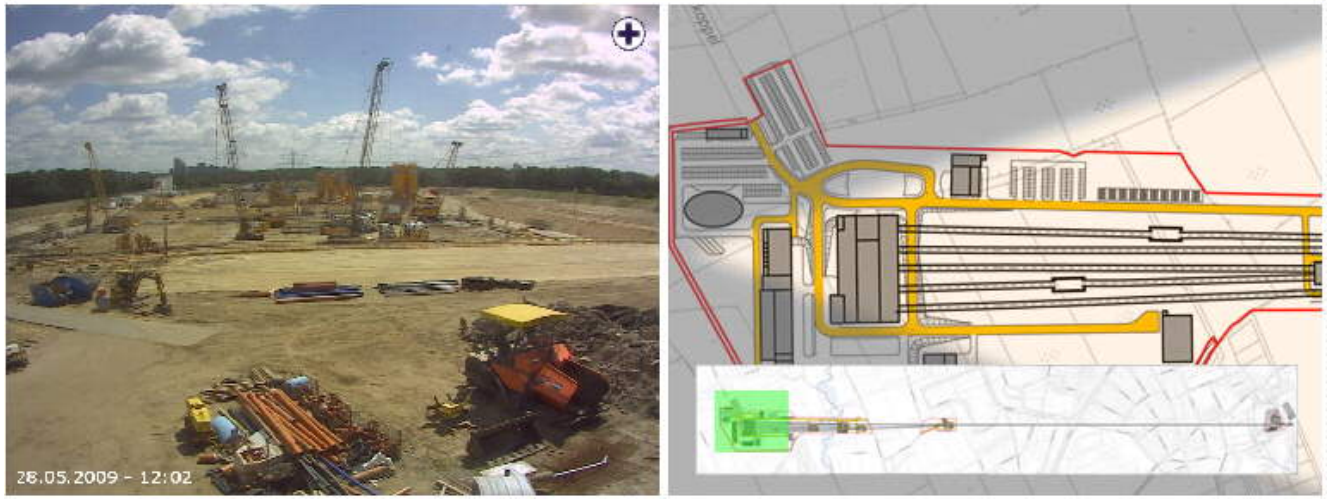
Scope of the SCS instrument is limited in the start-up approach as compared to the TDR scenario

Users are welcome to upgrade experimental possibilities of the SCS instrument providing their own instrumentation

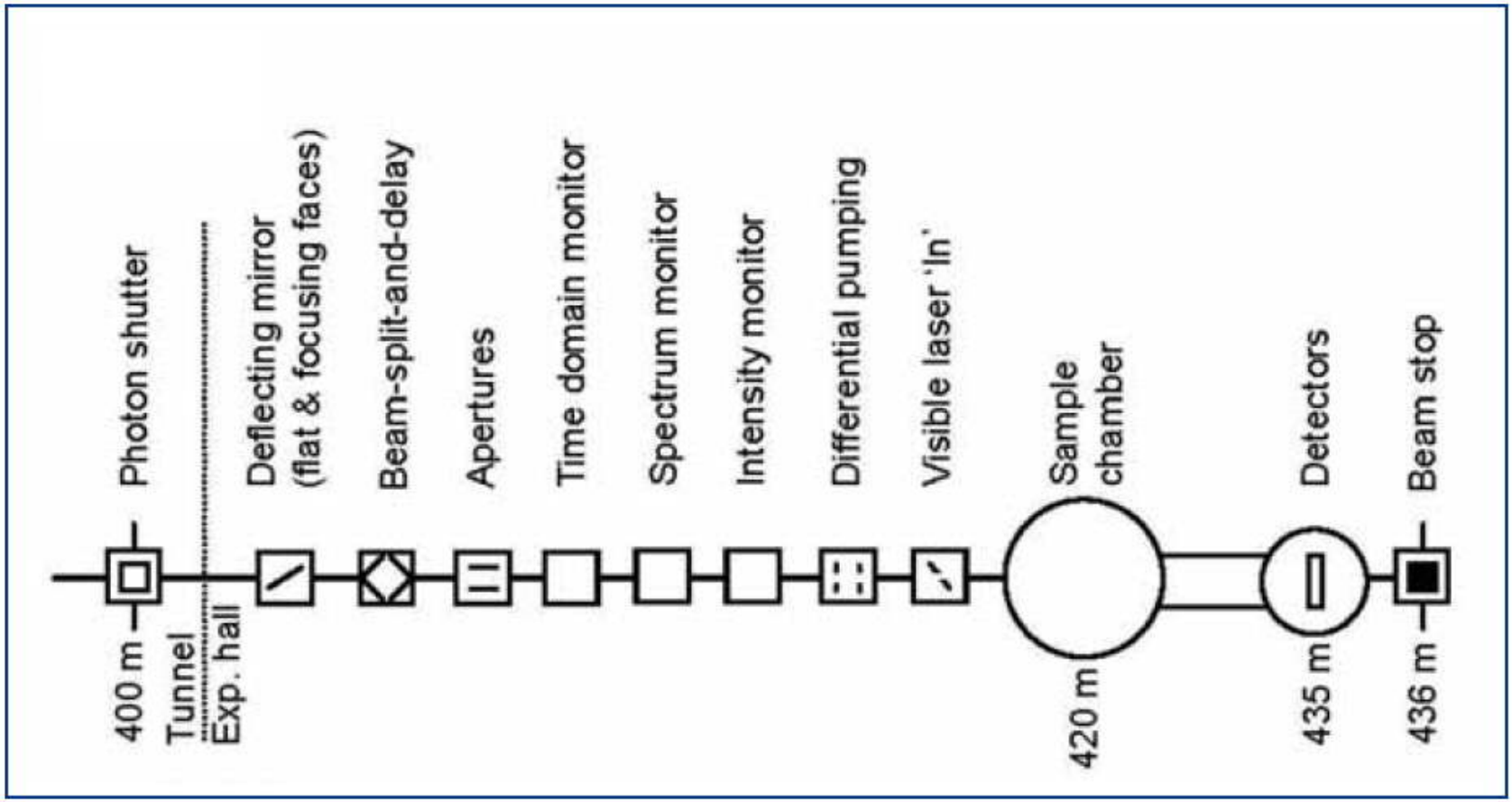
EPT team wish you

fruitful and pleasant Workshop

Camera Schenefeld



SCS: Photon Correlation Spectroscopy, Layout (TDR)

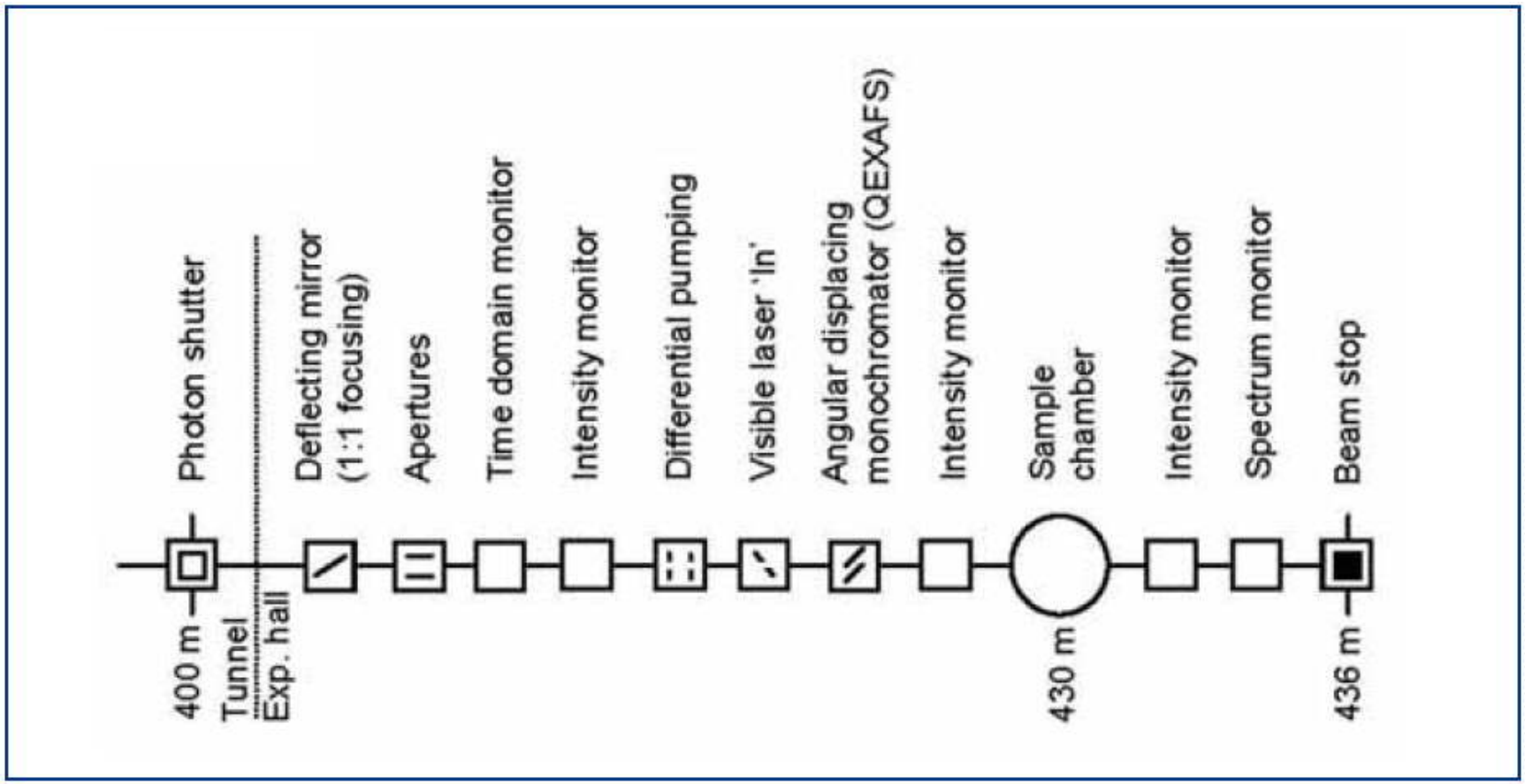


Diagnostics will be placed entirely upstream of the sample.
Distance sample-detector can be varied.

SCS: Photon Correlation Spectroscopy, Parameters (TDR)

Item	Purpose	Specification
Deflecting mirror	Flat, if using beamline focusing optics, curved for ~10 μm focusing	0.1 μrad angular stability, 0.1 μrad figure error, 0.1 nm surface roughness
Beam-split-and-delay	Splitting fundamental line into equal parts, delay 1 ps to 10 ns	High optical accuracy to maintain wavefront and x-ray pulse duration
Slits/apertures	Beam definition, beam halo cleaning	0.25 μm accuracy, 1 μm repeatability
Time domain monitor	Measurements of x-ray arrival-time x-ray with respect to visible laser, x-ray streak camera	
Spectrum monitor	Measurement of high harmonic content	Single pulse measurement, relative accuracy $<10^{-3}$
Intensity monitor	Measurement of incident photon flux	Transmissive (<5% absorption), single pulse measurement, relative accuracy $<10^{-3}$
Sample chamber	Sample positioning and orientation	x-y-z move (0.25/1 μm), two rotations (0.25/1 mdeg)
Detector	Measurement of diffraction pattern	2-D, 5K×5K pixels, 80×80 μm^2 pixel size
Alignment unit	Positioning and position verification	Permanently operating, accuracy ~100 μm

SCS Instrument: Spectroscopic Experiments, Layout (TDR)

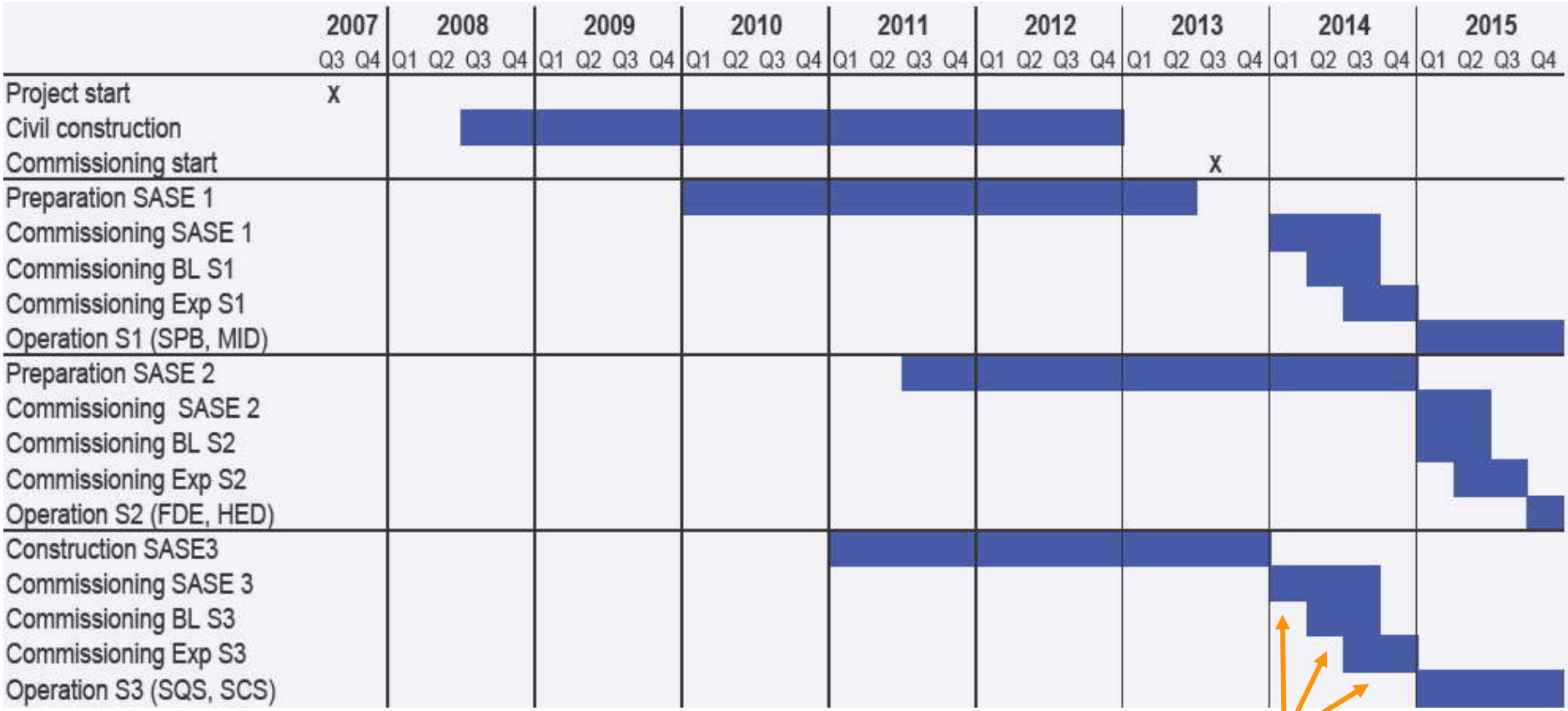


Diagnostics will be placed on both sides of the sample.

SCS Inst.: Spectroscopic Experiments, Parameters (TDR)

Item	Purpose	Specification
Deflecting optics	Horizontal deflection by 20 mrad, 1:1 focusing of monochromator exit	0.1 μrad angular stability, 0.3 μrad figure error, 0.1 nm surface roughness
Slits/apertures	Beam definition, beam halo cleaning	0.25 μm accuracy, 1 μm repeatability
Time domain monitor	Measurements of x-ray arrival-time x-ray with respect to visible laser	
Intensity monitor	Measurement of incident photon flux	Transmissive (<5% absorption), single pulse measurement, relative accuracy $<10^{-3}$
Differential pumping	Separation of beamline and instrument	
Monochromator	Angular displacing monochromator (QEXAFS)	0.1 μrad angular stability, 0.1 mrad asymmetry error
Intensity monitor	Measurement of photon flux behind dispersive element	Transmissive (<5% absorption), single pulse measurement, relative accuracy $<10^{-3}$
Sample chamber	Sample positioning and orientation	x-y-z move (0.25/1 μm), two rotations (0.25/1 mdeg)
Detector	Measurement of transmitted radiation	2-D, 2K×2K, 10-30 Hz
XES spectrometer	Space-resolved detection of x-ray emission from the sample	In-vacuum, 10-30 Hz frame rate
Intensity monitor	Measurement of transmitted photon flux	Transmissive (<5% absorption), single pulse measurement, relative accuracy $<10^{-3}$
Spectrum monitor	Measurement of high harmonic content	Single pulse measurement, relative accuracy $<10^{-3}$

Time Schedule



Commissioning SASE 3 (SCS & SQS)

Operation SASE 3 (SCS & SQS)

Output of the SQS Working Groups: Space Distribution