Photon Beamlines Commissioning

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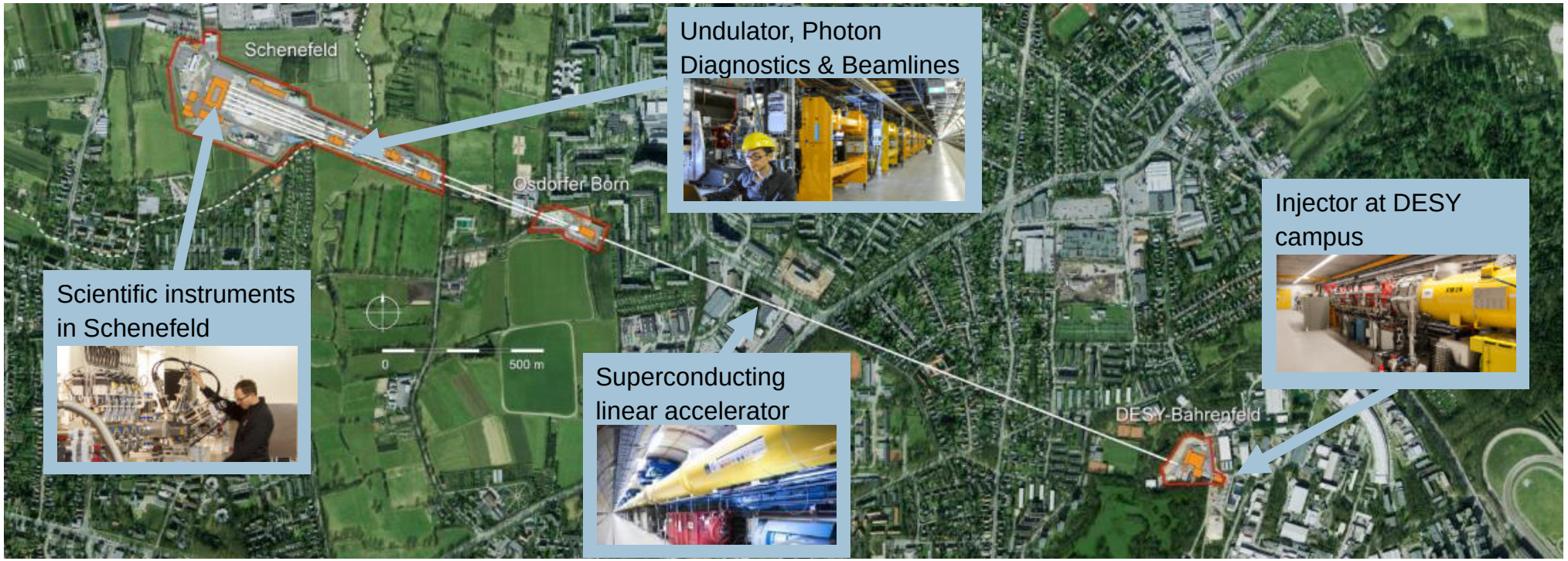
European XFEL

Enlightening Science

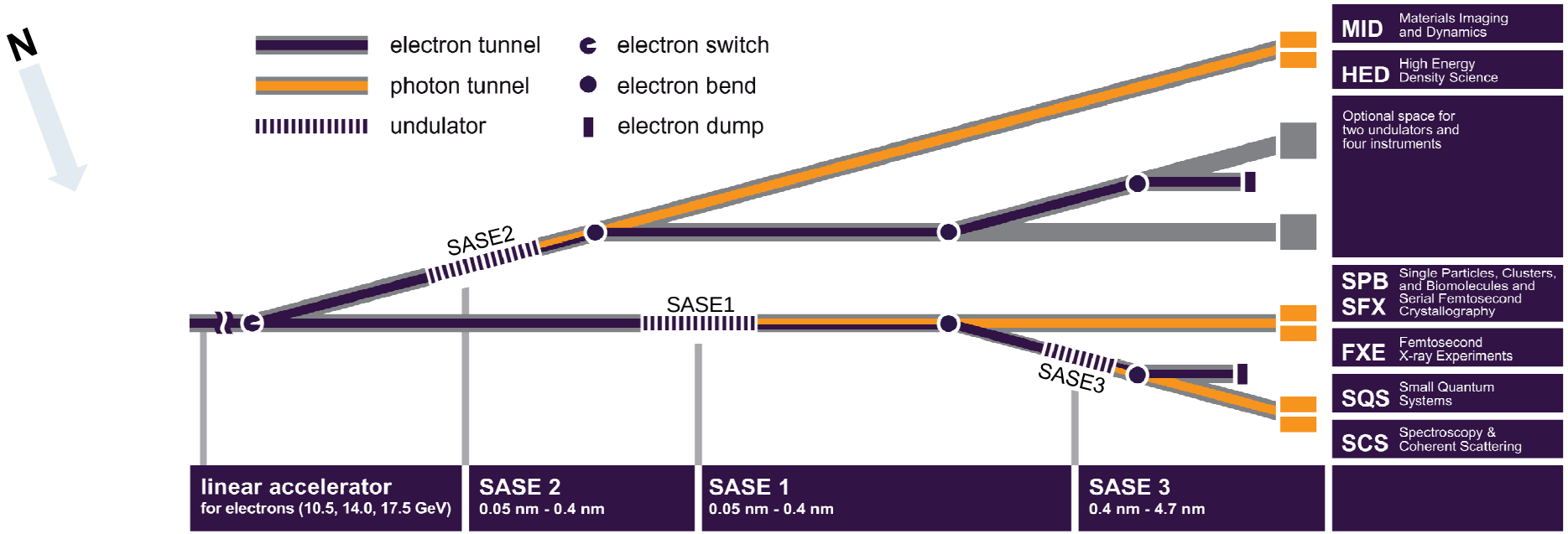
Content

- Photon system overview
  - …installed instrumentation in the photon tunnels
- Commissioning with beam
  - ...using spontaneous radiation
- First Lasing !
- Commissioning with FEL beam
- Beam studies
- Future

General layout of the European XFEL

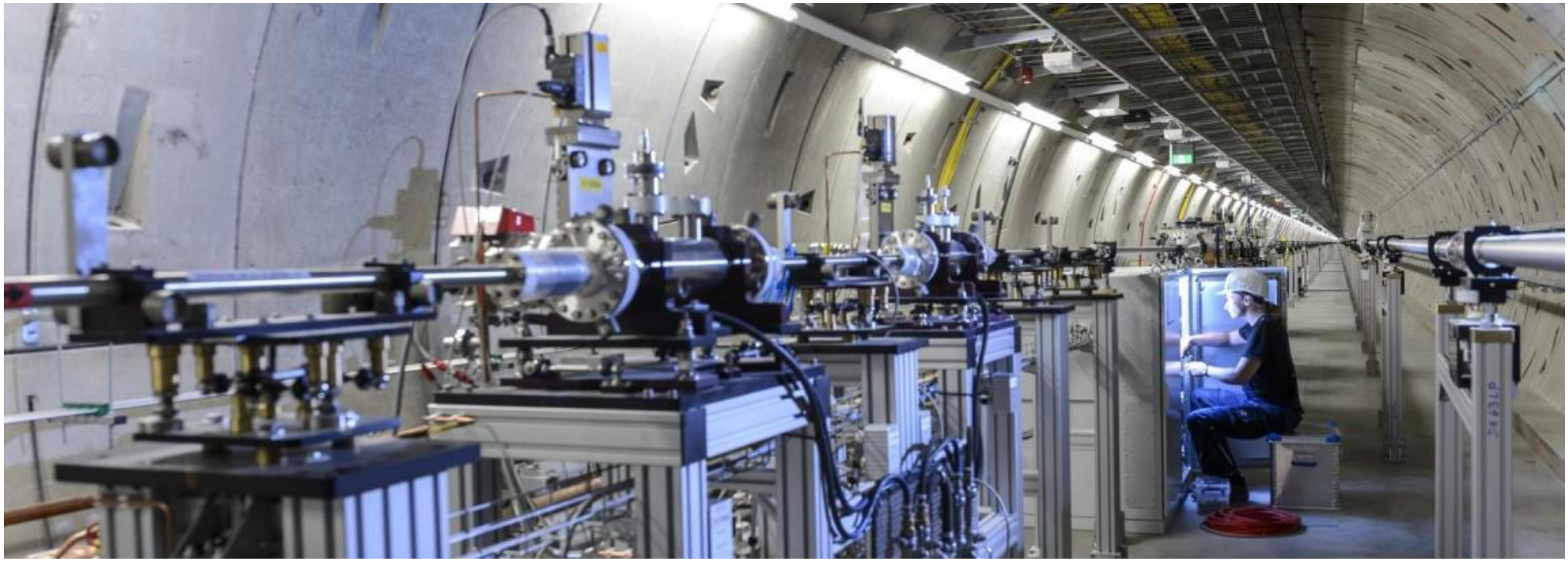


Beamline layout and experiment stations

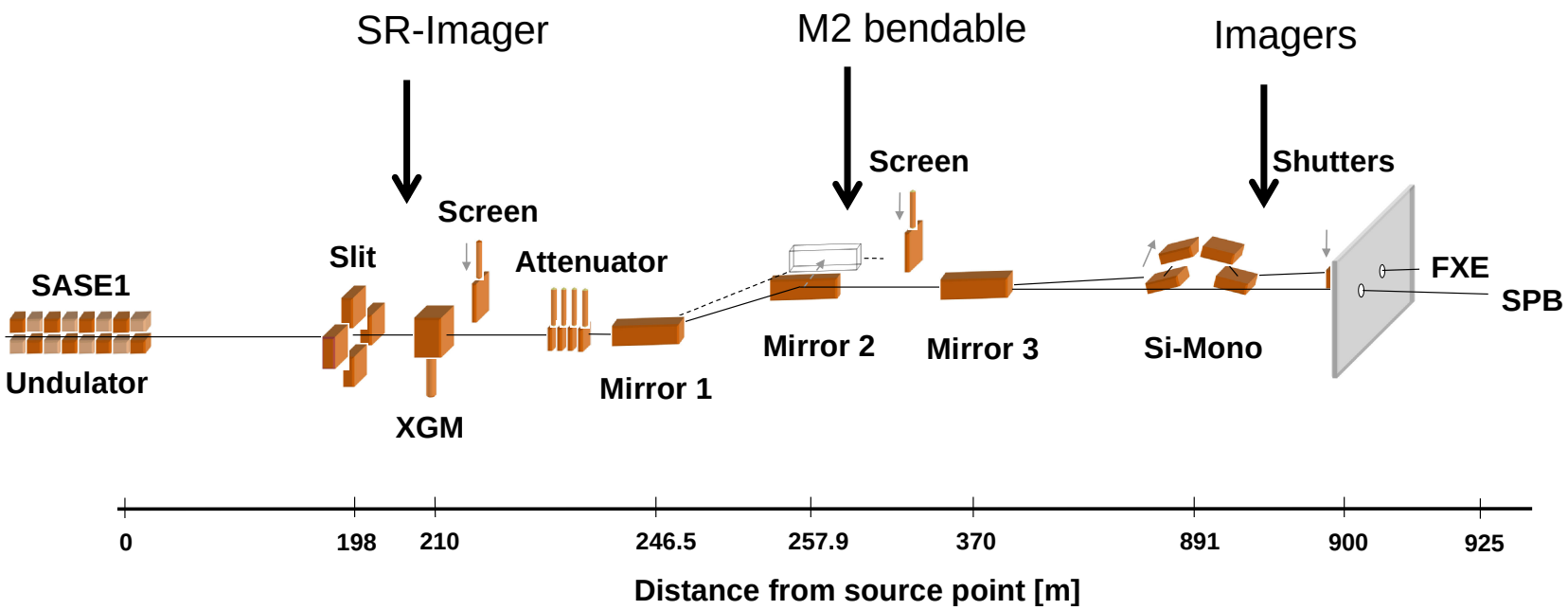


Photon beamlines

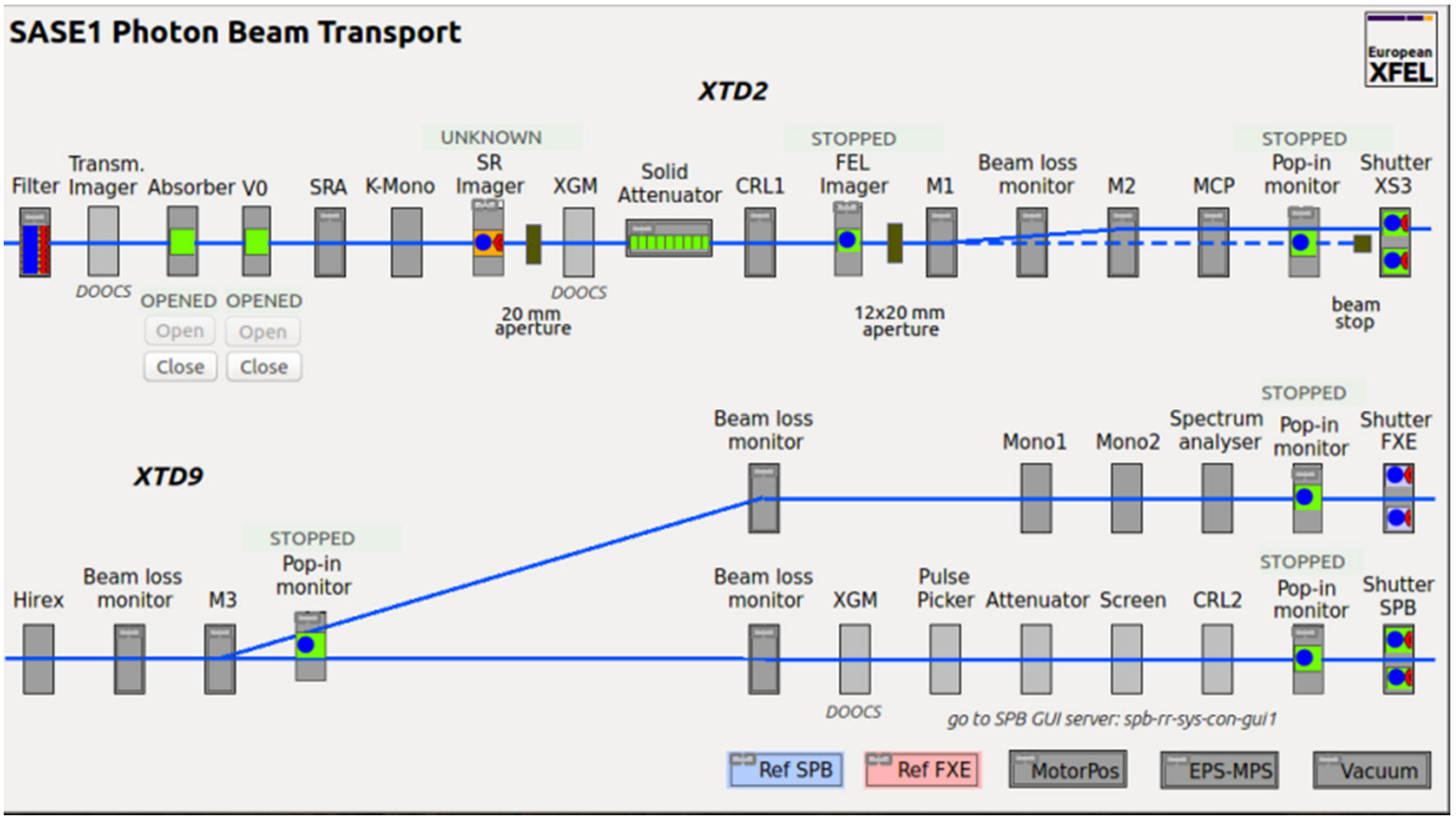
- SASE1 vacuum system and controls were successfully commissioned in early 2017 and are in operation since then



SASE1 photon beamline



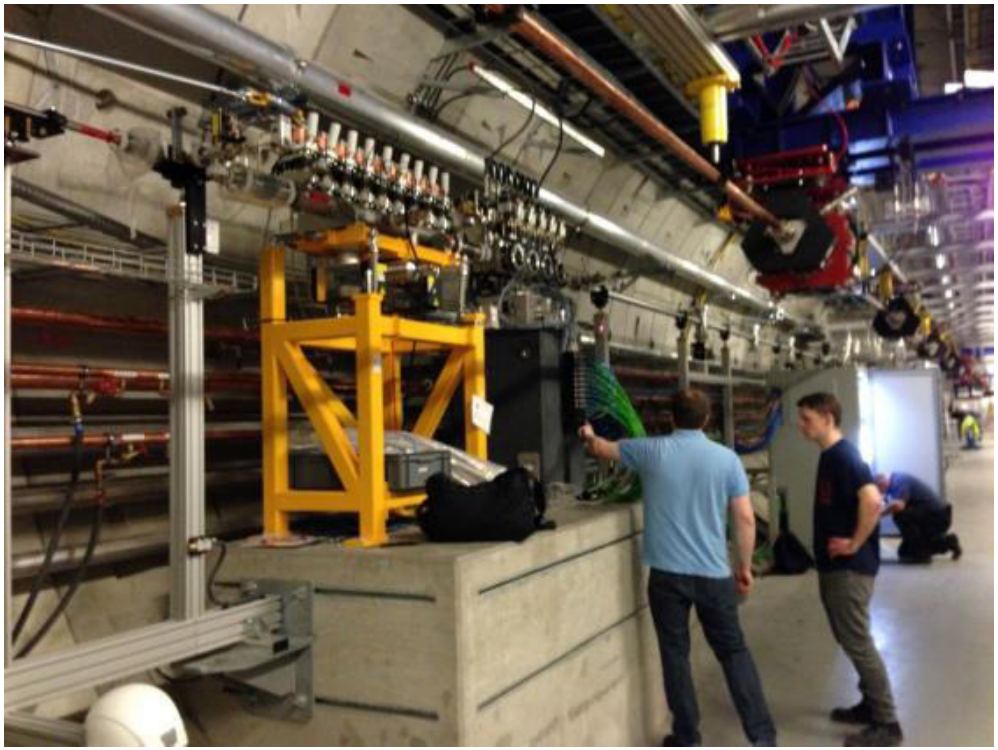
SASE1 photon beamline



Main karabo GUI scene

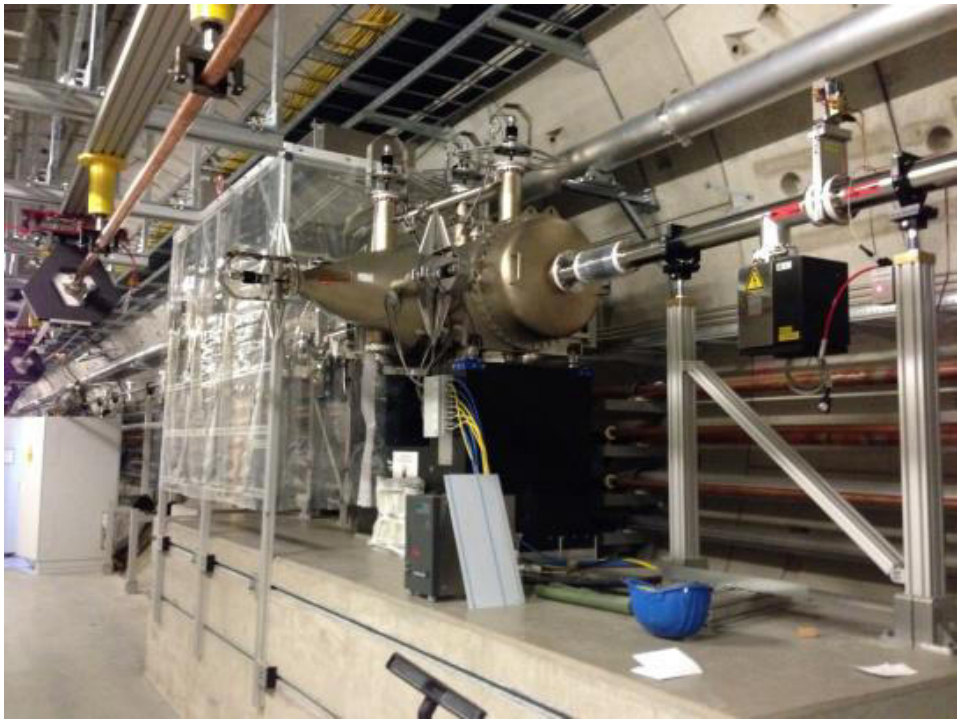
SASE1 photon beamline

XTD2, Attenuator, CRL



SASE1 photon beamline

XTD2, Mirror M1



SASE1 photon beamline

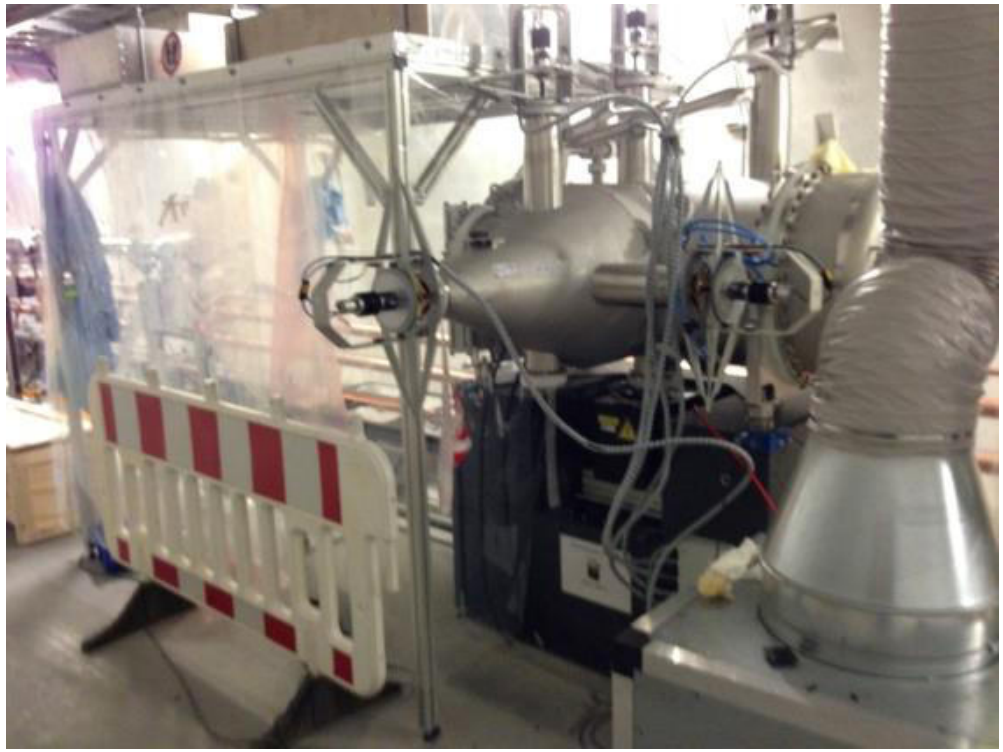
XTD2, Mirror M2

SASE1 photon beamline

XTD9, Hirex

SASE1 photon beamline

XTD9, M3



SASE1 photon beamline

XTD9, 500 m pipes

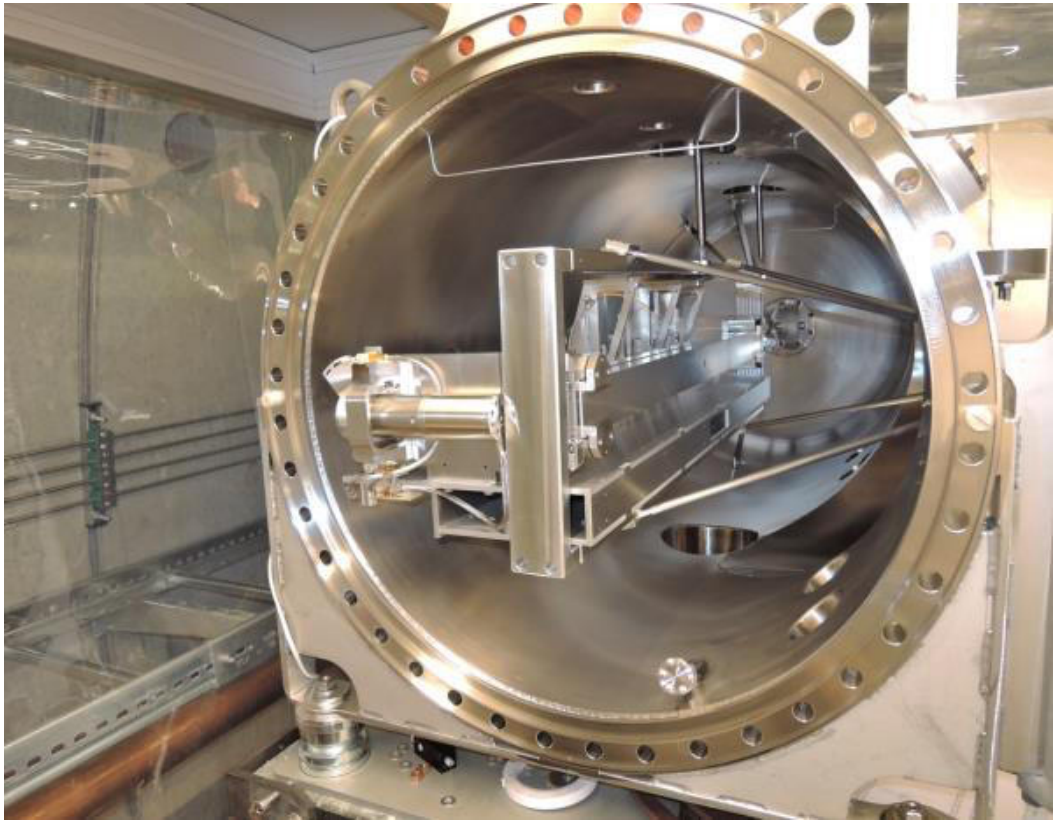
SASE1 photon beamline

XTD9, XGM

SASE1 photon beamline

XTD9, CRL, Shutters,
Pop-in Monitors

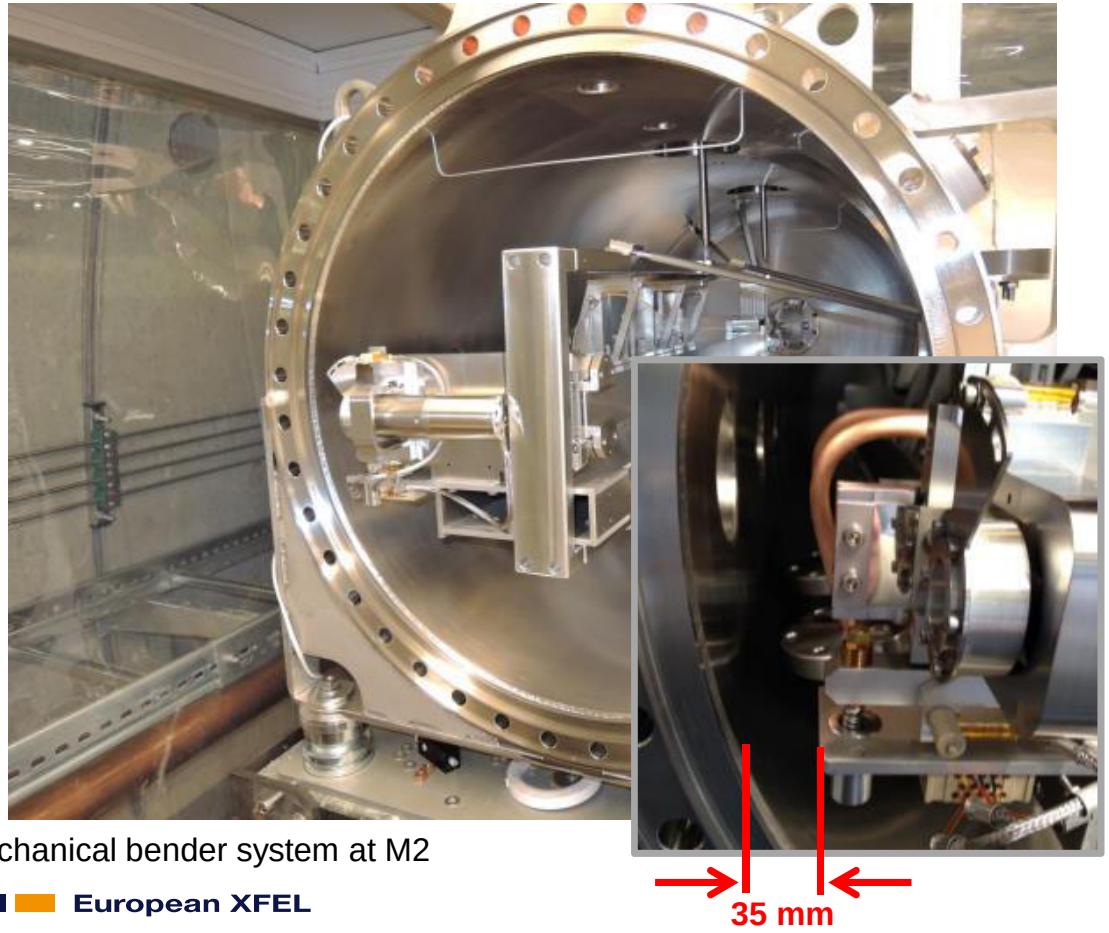
Installation of mirrors



Installation of mechanical bender system at M2

Flat mirror system M3

Installation of mirrors

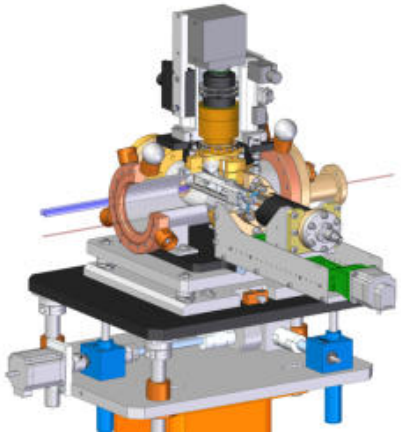


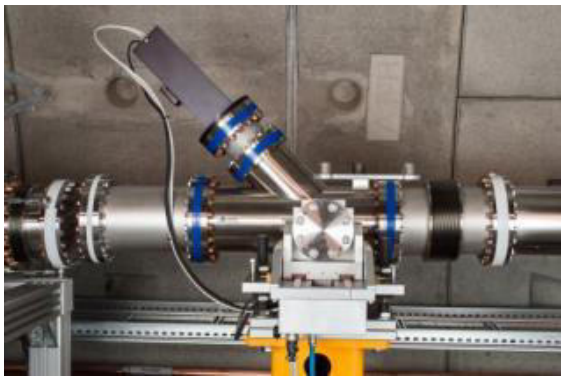
Installation of mechanical bender system at M2

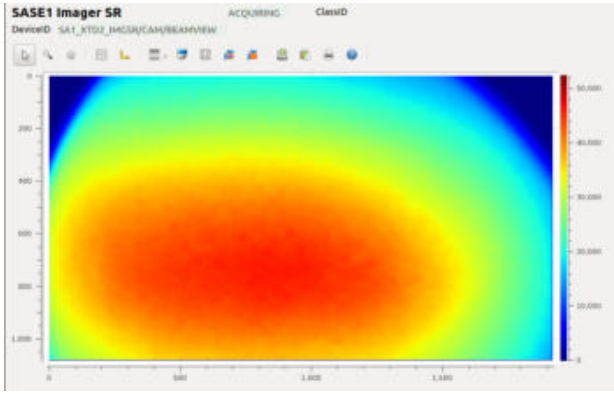
Flat mirror system M3

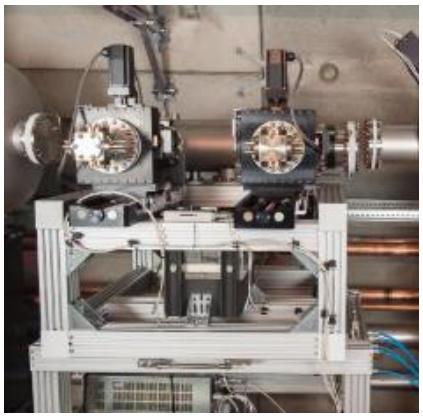
M2, M3 have to drive ±30 mm for adjustable offset
(collision with cooling system)
➔ **no cooling on M2,3 initially available**

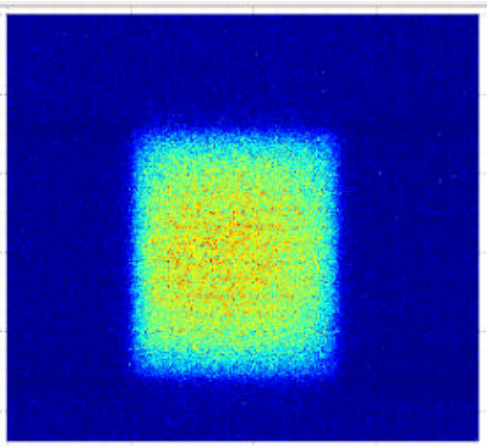
Photon diagnostics: prepare, support & observe lasing





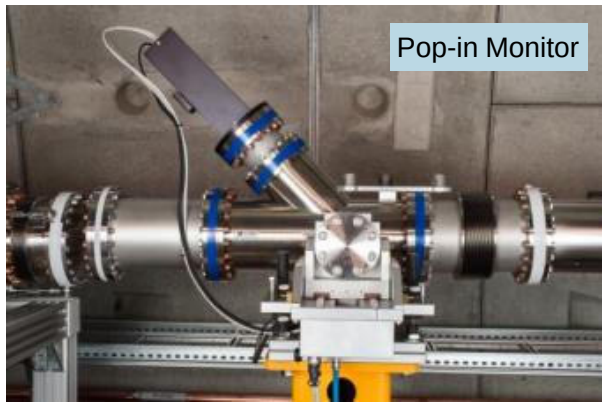


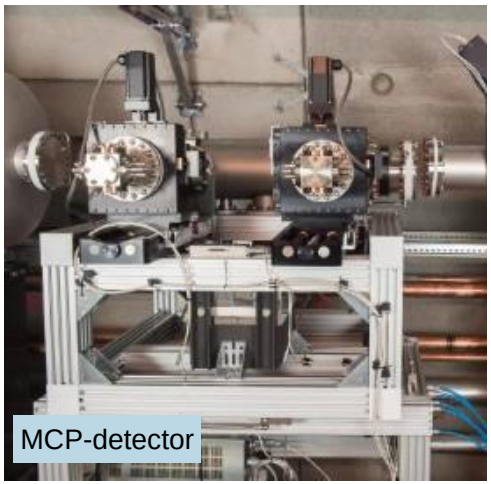




SASE1 photon diagnostics – XTD2

- all SASE1 diagnostics systems (XTD2 and XTD9) commissioned



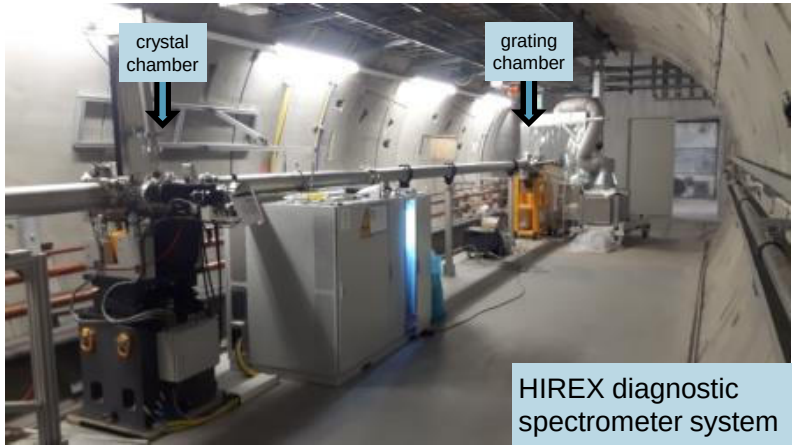


SASE1 photon diagnostics – XTD9

- all SASE1 diagnostics systems (XTD2 and XTD9) commissioned


XGM@XTD9


HIREX crystal chamber



HIREX diagnostic spectrometer system



Pop-in Monitors Type I and II-45

Commissioning with X-rays

Photon Commissioning Team
(14 people from several groups)

Device Experts

Visiting scientists

SASE1 photon commissioning time line

- May 2: First lasing around 1 keV (with IMGTR)
- May 12: First beam (spontaneous radiation) into photon beam lines.
- May 24: First hard X-ray lasing at 6 keV
- May 27: Beam through beam transport onto SPB and FXE shutters
- June 23: First beam into experiment hall
- one week split beam delivery to SPB + FXE, then dedicated in 10h / 14h split

Total:
23 days beam (14 days with SASE beam) for optics+diagnostics commissioning with photons
43 days for SPB/FXE

- First users: Sept. 14 - Sept. 30: 4 months after first lasing

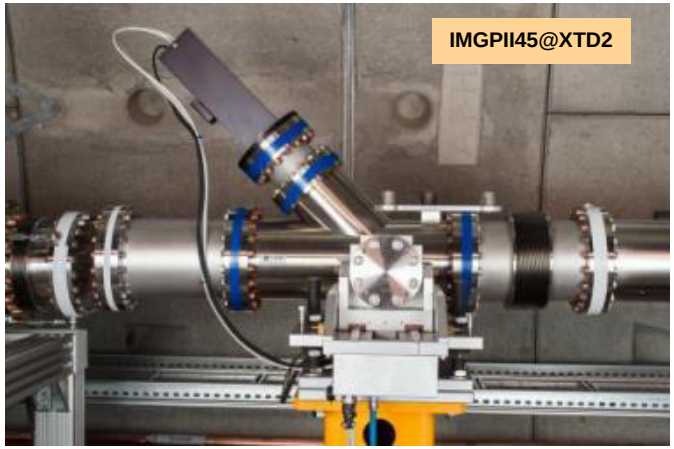
Mai		Juni		Juli		August		September	
1 Mo	T4D	1 Do	Acc. Studies	1 Sa	Acc. Studies	1 Di	Acc. Studies	1 Fr	Photon Comm.
2 Di	SASE SA1	2 Fr	Acc. Studies	2 So	Acc. Studies	2 Mi	Acc. Studies	2 Sa	Exp. Comm.
3 Mi	Close SA1	3 Sa	Acc. Studies	3 Mo		3 Do	Photon Comm.	3 So	Exp. Comm.
4 Do	SASE SA1	4 So	Acc. Studies	4 Di		4 Fr	Photon Comm.	4 Mo	Exp. Comm.
5 Fr	SASE SA1	5 Mo	Acc. Studies	5 Mi		5 Sa	Photon Comm.	5 Di	Acc. Studies
6 Sa	SASE SA1	6 Di	Acc. Studies	6 Do		6 So	Photon Comm.	6 Mi	Photon Comm.
7 So	SASE SA1	7 Mi	Acc. Studies	7 Fr		7 Mo	Photon Comm.	7 Do	Photon Comm.
Mo	SASE SA1	8 Do	Acc. Studies	8 Sa		8 Di	Acc. Studies	8 Fr	Photon Comm.
9 D	SASE SA1	9 Fr	Photon Comm.	9 So		9 Mi	Acc. Studies	9 Sa	Photon Comm.
10 Mi	Startup	10 Sa	Photon Comm.	10 Mo	Acc. Studies	10 Do	Photon Comm.	10 So	Exp. Comm.
11 Do	Acc. Studies	11 So	Photon Comm.	11 Di	Acc. Studies	11 Fr	Photon Comm.	11 Mo	Exp. Comm.
12 Fr	Acc. Studies	12 Mo	Acc. Studies	12 Mi	Acc. Studies	12 Sa	Exp. Comm.	12 Di	Setup
13 Sa	Acc. Studies	13 Di	Acc. Studies	13 Do	Acc. Studies	13 So	Exp. Comm.	13 Mi	Setup
14 So	Acc. Studies	14 Mi	Acc. Studies	14 Fr	Acc. Studies	14 Mo		14 Do	
15 Mo	Acc. Studies	15 Do	Photon Comm.	15 Sa	Acc. Studies	15 Di			User
16 Di	Acc. Studies	16 Fr	Photon Comm.	16 So	Photon Comm.	16 Mi		16 Sa	User
Mi	Photon Comm.	17 Sa	Photon Comm.	17 Mo	Photon Comm.	17 Do		17 So	User
18 Do	Photon Comm.	18 So	Photon Comm.	18 Di	Acc. Studies	Fr		18 Mo	User
19 Fr	Photon Comm.	19 Mo	Photon Comm.	19 Mi	Acc. Studies	19 Sa		19 Di	Setup
20 Sa	Photon Comm.	20 Di	Photon Comm.	20 Do	Photon Comm.	20 So		20 Mi	Setup
So	Photon Comm.	21 Mi	Photon Comm.	21 Fr	Photon Comm.	21 Mo	Startup	21 Do	User
22 Mo	Photon Comm.	22 Do	Photon Comm.	22 Sa	Exp. Comm.	22 Di	Acc. Studies	22 Fr	User
23 Di	Acc. Studies	23 Fr	Photon Comm.	23 So	Exp. Comm.	23 Mi	Acc. Studies	23 Sa	User
24 Mi	Acc. Studies	24 Sa	Exp. Comm.	24 Mo	Exp. Comm.	24 Do	Acc. Studies	24 So	User
25 Do	Acc. Studies	25 So	Exp. Comm.	25 Di	Startup	25 Fr	Photon Comm.	25 Mo	User
Fr	Photon Comm.	26 Mo	Exp. Comm.	26 Mi	Acc. Studies	26 Sa	Photon Comm.	26 Di	Setup
27 Sa	Photon Comm.	27 Di	Exp. Comm.	27 Do	Exp. Comm.	27 So	Exp. Comm.	27 Mi	Setup
28 So	Photon Comm.	28 Mi	Exp. Comm.	28 Fr	Exp. Comm.	28 Mo	Exp. Comm.	28 Do	User
29 Mo	Acc. Studies	29 Do	Exp. Comm.	29 Sa	Exp. Comm.	29 Di	Acc. Studies	29 Fr	User
30 Di	Startup	30 Fr	Acc. Studies	30 So	Exp. Comm.	30 Mi	Photon Comm.	30 Sa	User
31 Mi	Acc. Studies			31 Mo	Acc. Studies	31 Do	Photon Comm.		

Imagers in SASE1

Transmissive Imager (IMGTR) = “OTRC”

2D-imager-SR (IMGSR)

2D-imager-FEL (IMGFEL)



Pop-in Monitors

for undulator commissioning with SR-radiation

for First Lasing and FEL analysis

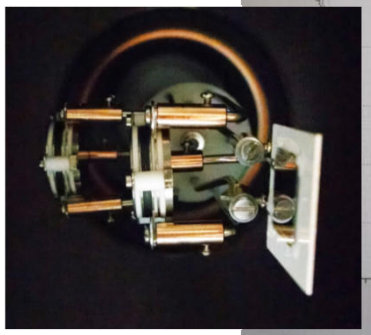
for beam finding, alignment & tuning

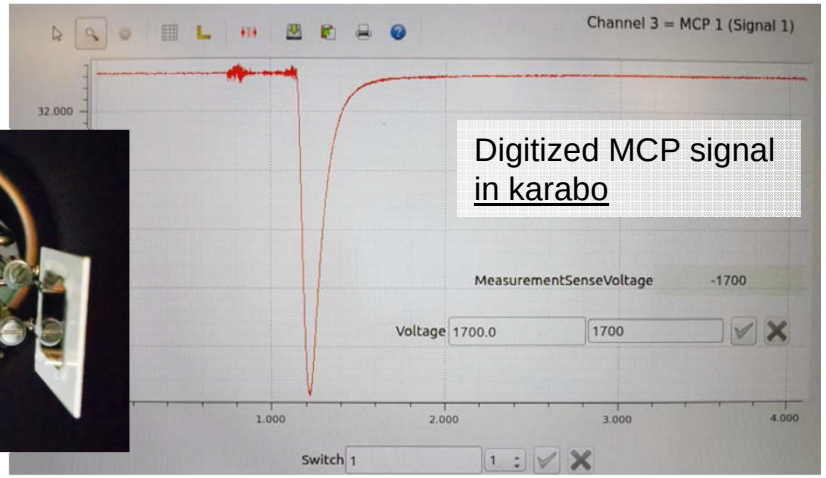
Ref.: A.Koch, XPD

MCP*-based detector

- Invasive diagnostics device for beam commissioning:
  - intensity monitoring from nJ up to mJ SASE level
  - gain studies
- 2 manipulators with 3 regular MCPs, 1 photodiode, 1 intensified imager (BOS-MCP)
- Commissioned Capabilities
  - Regular MCP signal peak intensity sent from karabo to DOOCS for SASE tuning
  - Intensified imager not often used due to good performance of IMGFEL


JINR-colleagues (Brovko,Grebentsov)





Digitized MCP signal in karabo

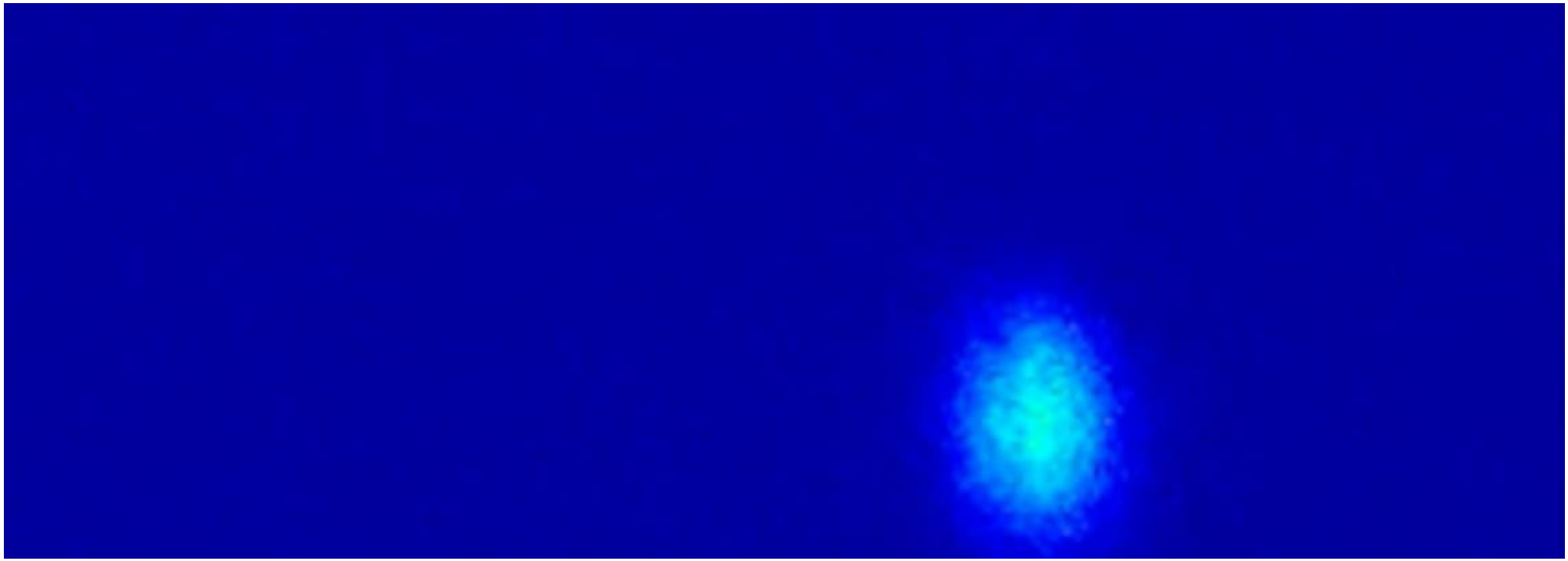
* multi-channel plate

First Lasing

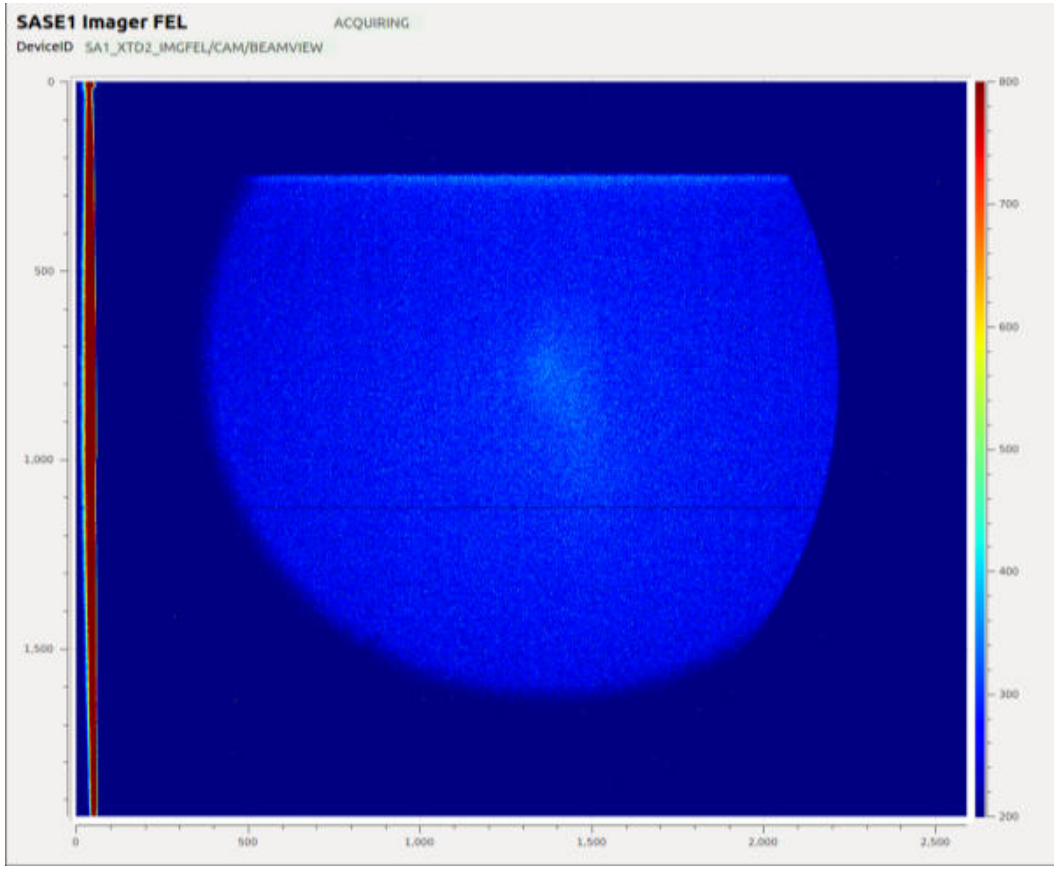
.

2 May 2017—first lasing!

First lasing of European XFEL at 1.5keV



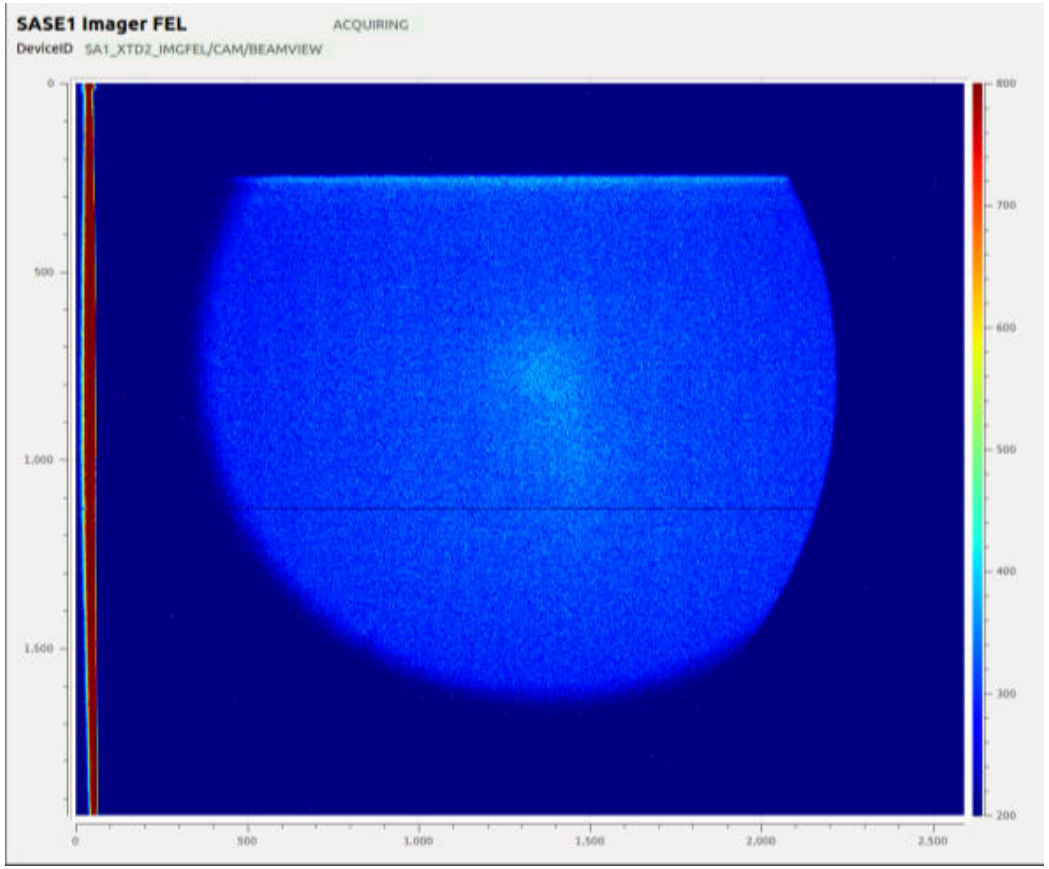
SASE tuning at 6keV – search for lasing



8 undulators closed

24.05.2017 20:32

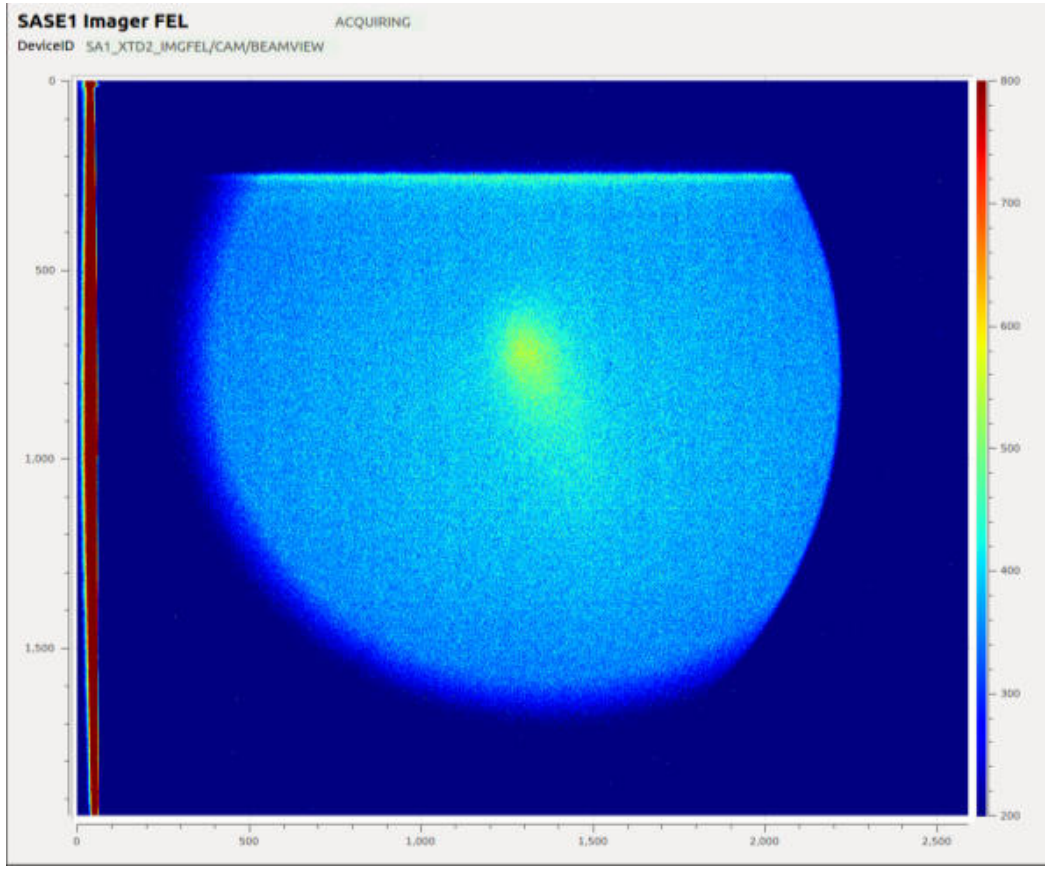
SASE tuning at 6keV – search for lasing



10 undulators closed

24.05.2017 20:39

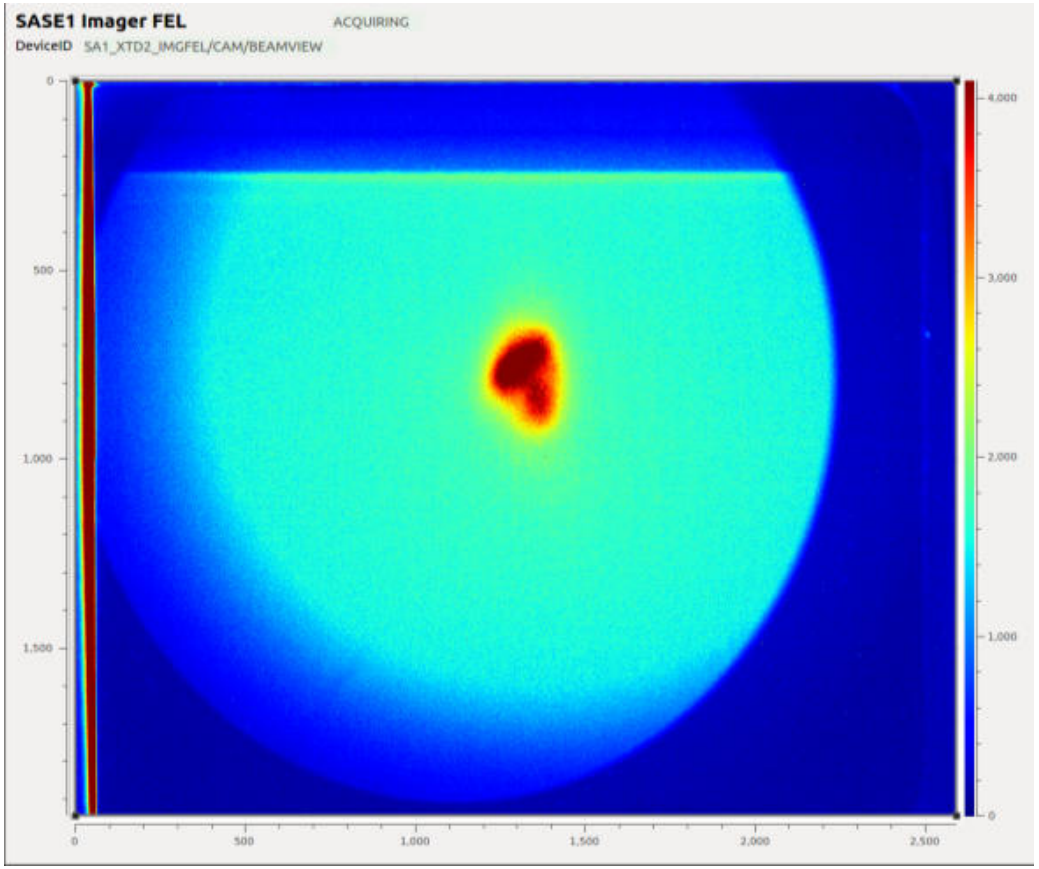
SASE tuning at 6keV – search for lasing



14 undulators closed

24.05.2017 20:51

LASING !!

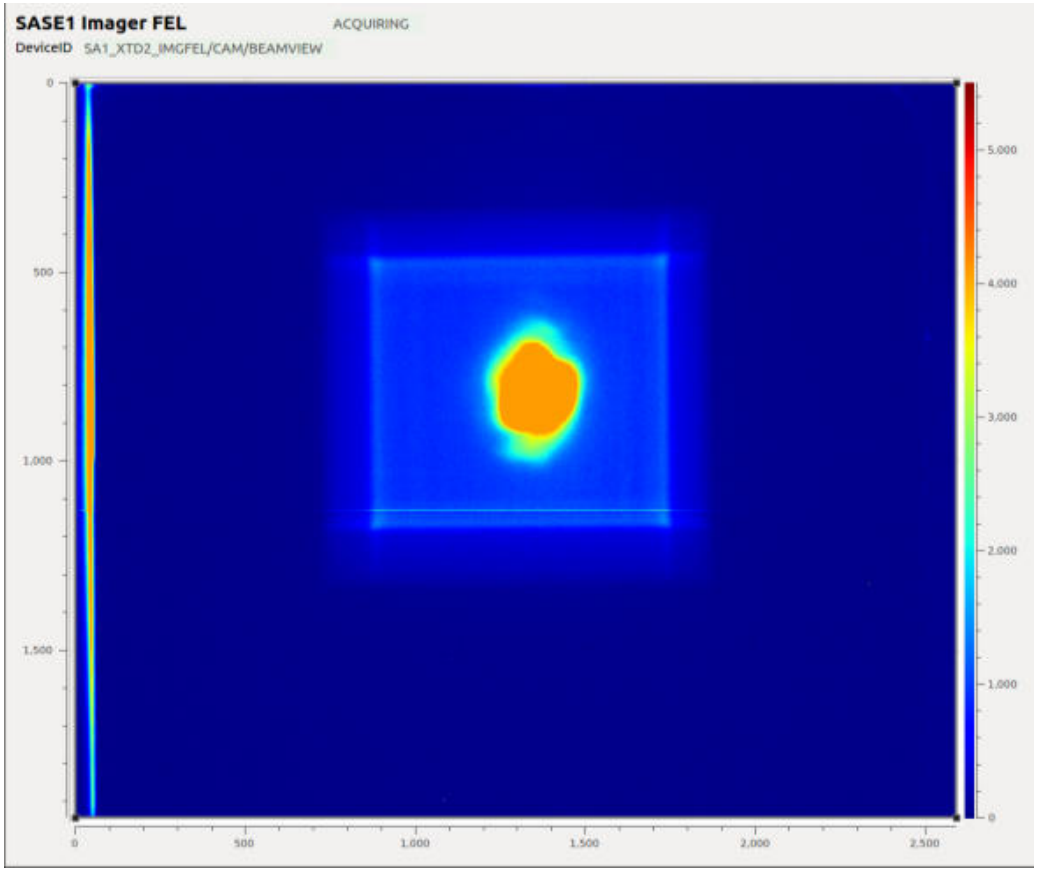


21 undulators closed

First Hard X-ray lasing at European XFEL

24.05.2017 21:19

Higher intensity

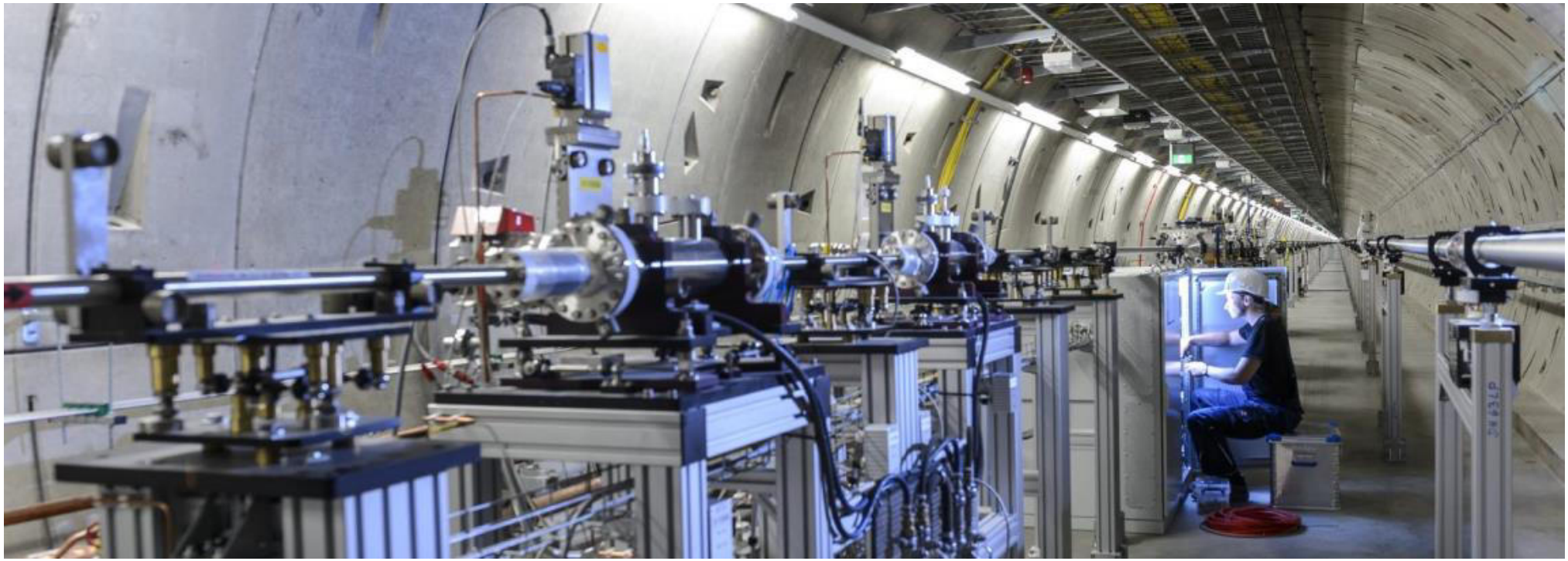


SRA closed around beam

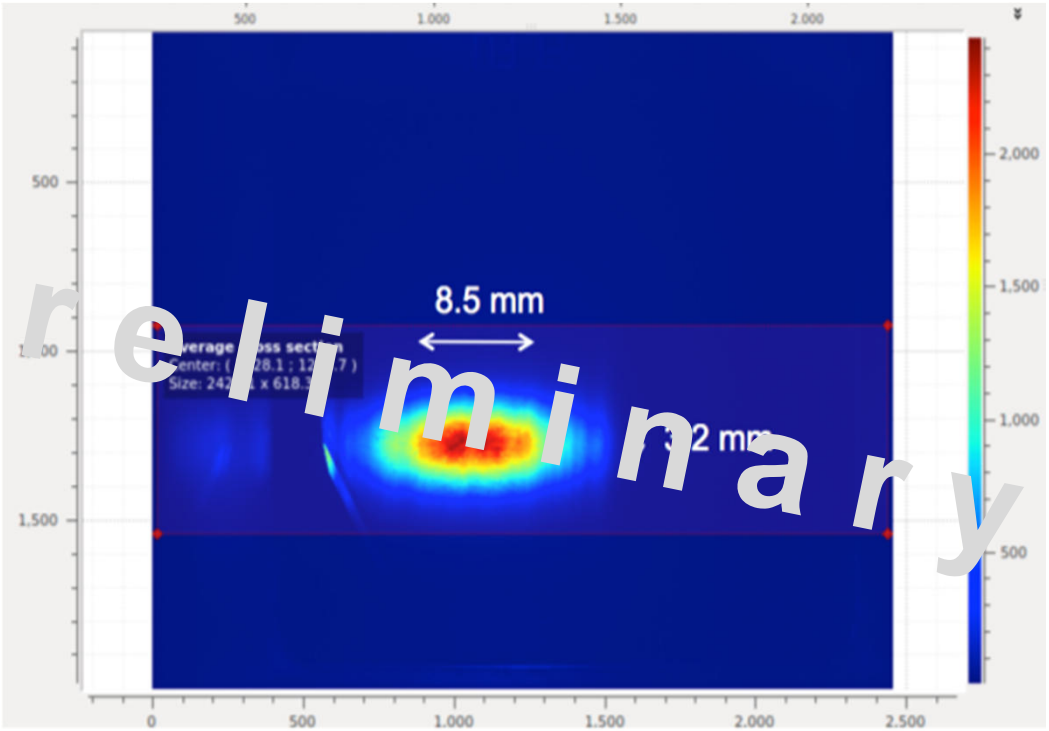
Xray-intensity so high,
that scintillator saturates

24.05.2017 23:53

Photon beamlines



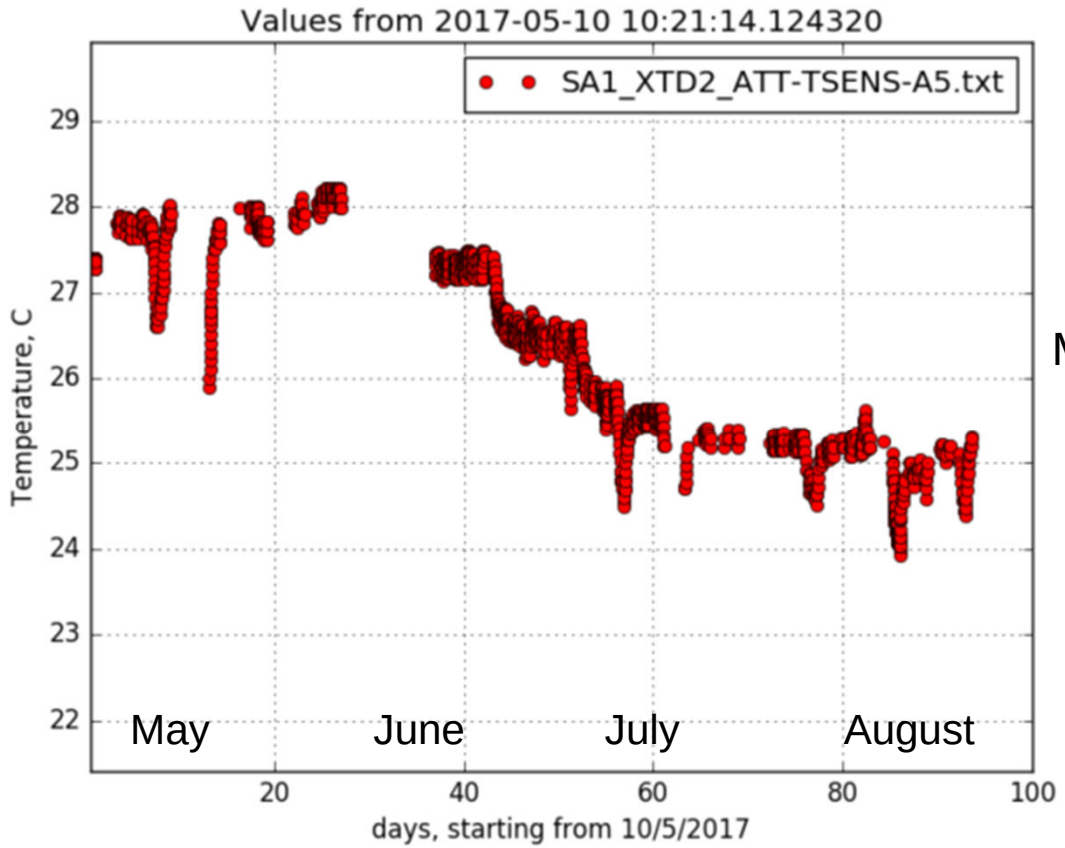
First time at the end of the beamline: Performance of X-ray mirrors (May 27, 6.2 keV SASE)



First beam at the end of XTD9, SPB screen, 650 m behind M2

- Vertical beamsize close to theoretical value
- Beam distortions rather from cut-offs than mirror profiles
- No dust particles
- Large horizontal beam size large due to bender

Temperature in the XTD2 tunnel

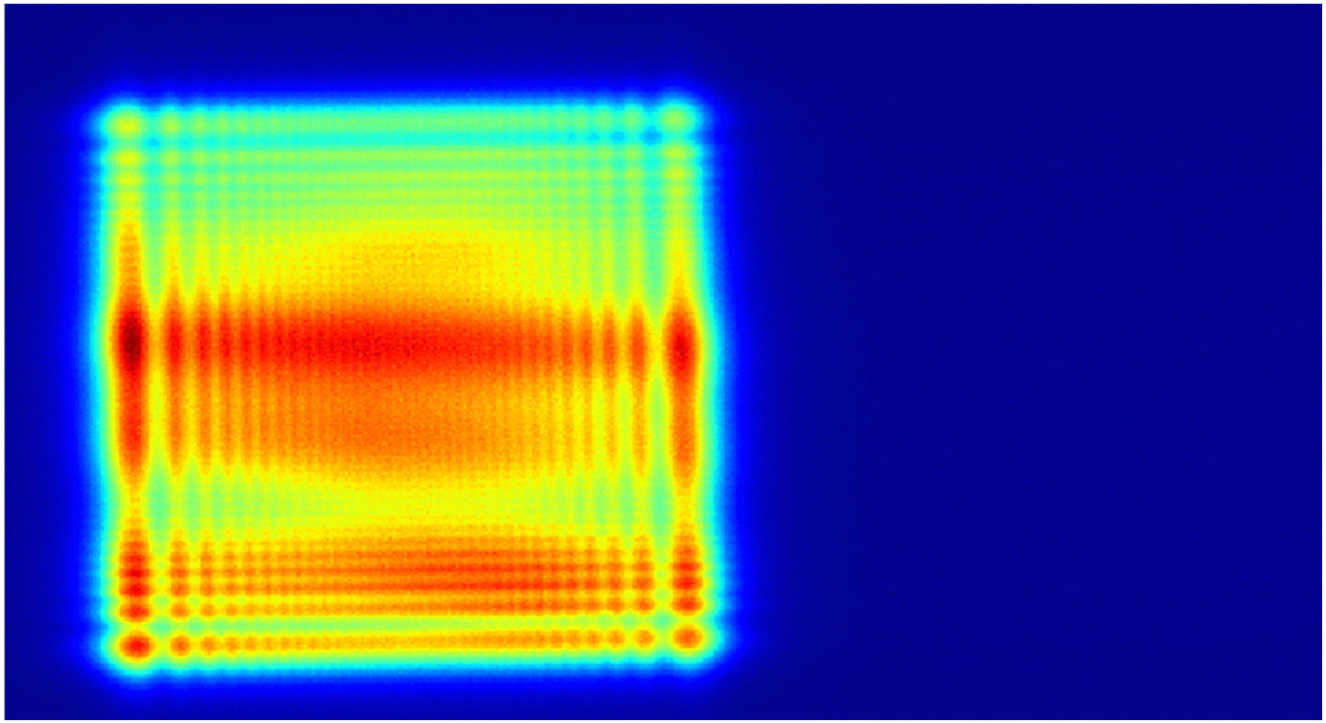


Initial temperature in XTD2 tunnel

M2 bender now ‘just’ in operation range

Temperature metrology lab

X-ray laser beam quality



- Fresnel pattern recorded on 30 June 2017
- Diffraction pattern shows an interference pattern that is classic for high quality laser beams

Online diagnostics

W.Freund, J.Liu, A.Koch, J.Grünert

Online diagnostics: X-ray gas monitor (XGM)

- Intensity & beam position
- Indestructible
- Pulse resolved
- Capable of 4.5 MHz rate
- Operation 24 / 7

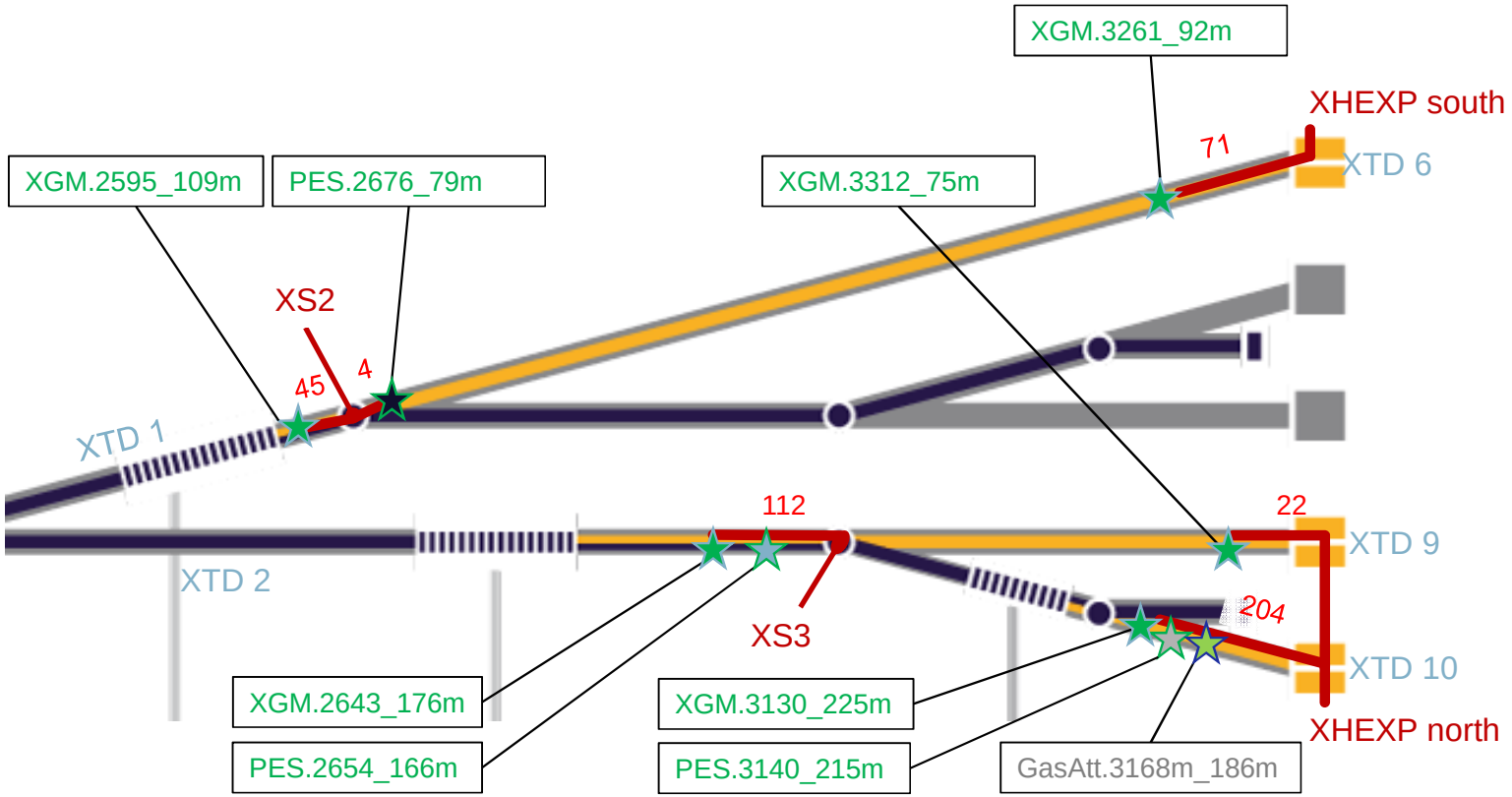
- 5 XGMs in tunnels – 2 in operation
  - Developed and built by K.Tiedtke group at DESY/FLASH
  - Temp. protection by UPS
  - Special cables (>50), crates, grounding
  - Technical Commissioning with DESY
    - ► HV-tests / -conditioning

- DAQ
  a) in DOOCS (server by DESY)
  b) in karabo (CAS / ITDM)

XGM electronics

- Crates:
  - MTCA
  - HV crate
  - ADAM&FEMTO crate
  - UPS
  - PLC/Beckhoff: vac,mov,eps
- Cables
  - Vacuum (gauges and pumps, to controllers)
  - Vacuum and gas supply (to Beckhoff)
  - Serial DOOCS control cables
  - HV
  - Fast Signals (to ADC)
  - Network connections
  - Power lines (to UPS and regular)
  - Grounding

Gas Supply System (for the tunnels, XGM/PES)



Legende:

[Gerät].[LA Z-Koordinate]_[Entfernung Schrank]m

XX = max. Entfernung Verbraucher bis nächstes Gebäude

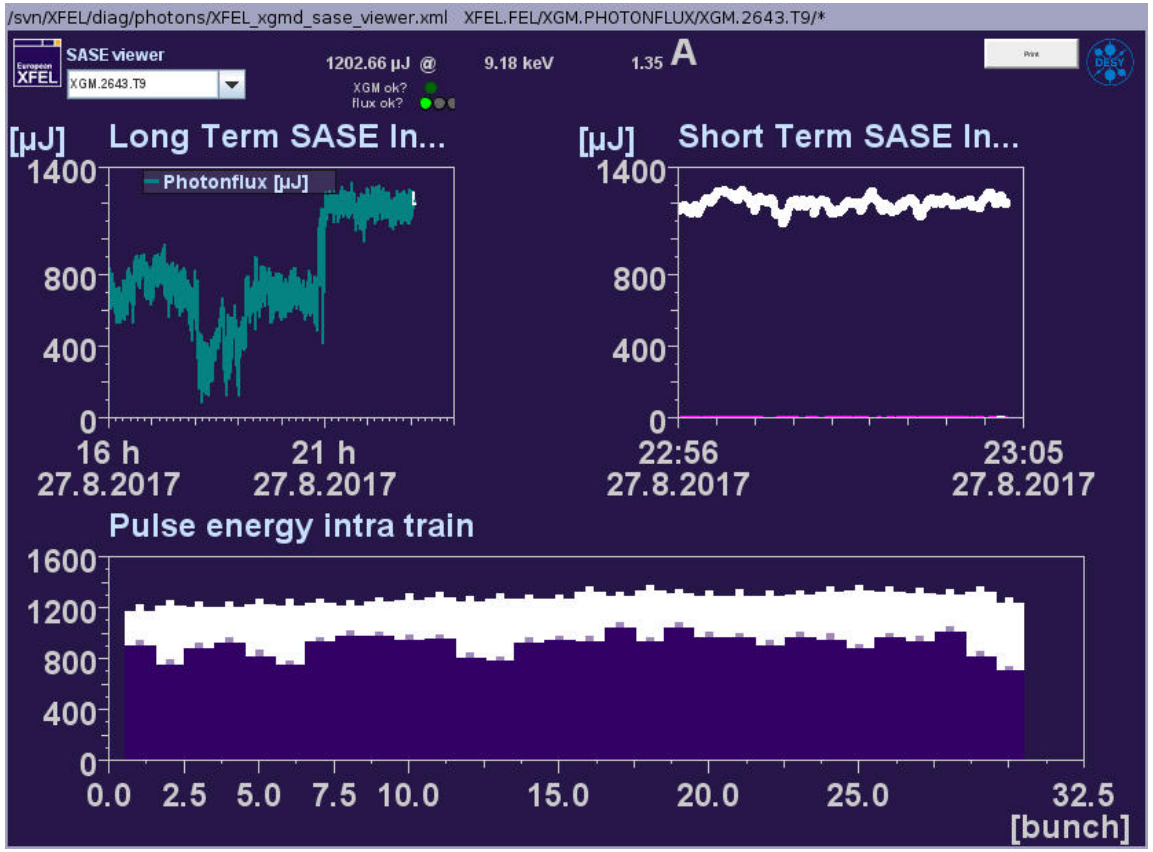
Gas Supply System (for the tunnels)

- by Dräger and DERU, coordinated by XPD
- Some numbers:
  - ~4km of stainless steel pipes
  - 4 gas cabinets
  - 9 consumer points / distribution panels
- Construction
  - Contractual start: 7.1.2016
  - Actual handover 2.3.2017

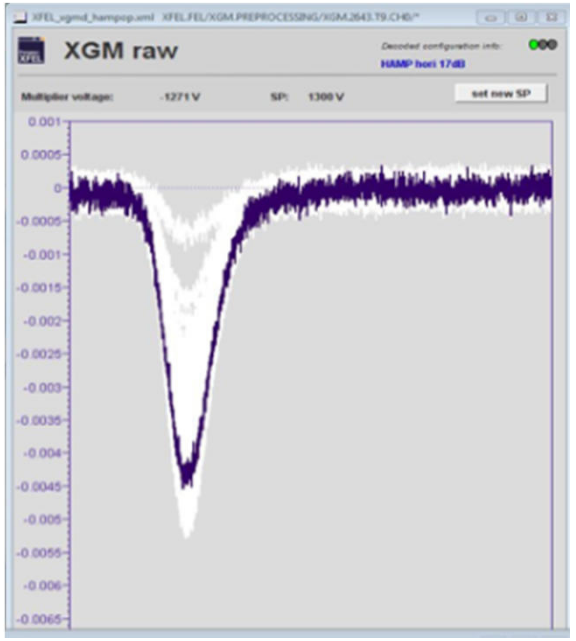

Panel @XTD6


Distribution Panel at XGM@XTD2

Online diagnostics: X-ray gas monitor (XGM)

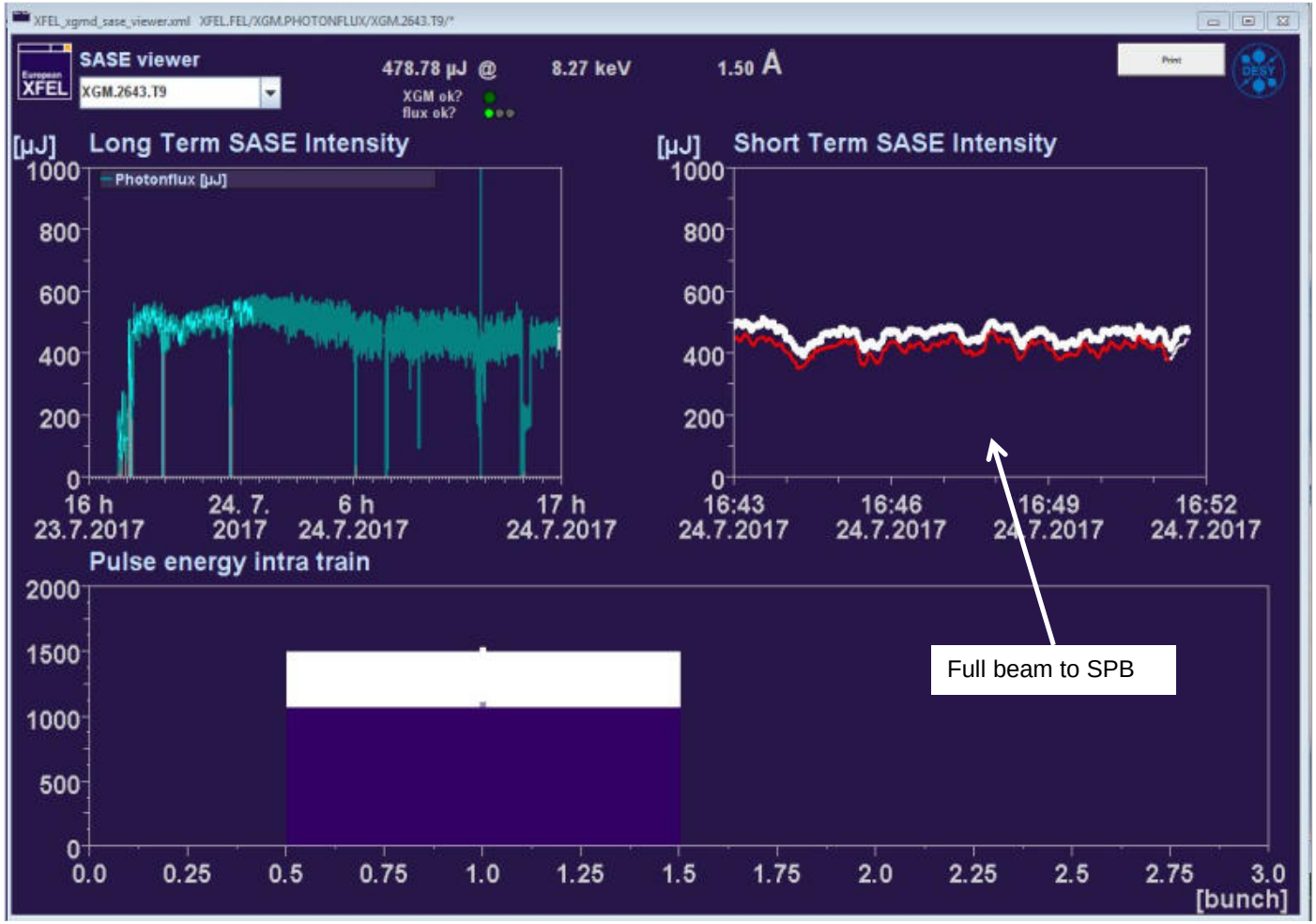


- Intensity & beam position
- Indestructible
- Pulse resolved
- Capable of 4.5 MHz rate
- Operation 24 / 7



Typical operation of both XGMs in SASE1

(here : single bunch mode)



white: XGM @XTD2
red: XGM @ XTD9

Single bunch mode

Xe at 5E-5 mbar (both)

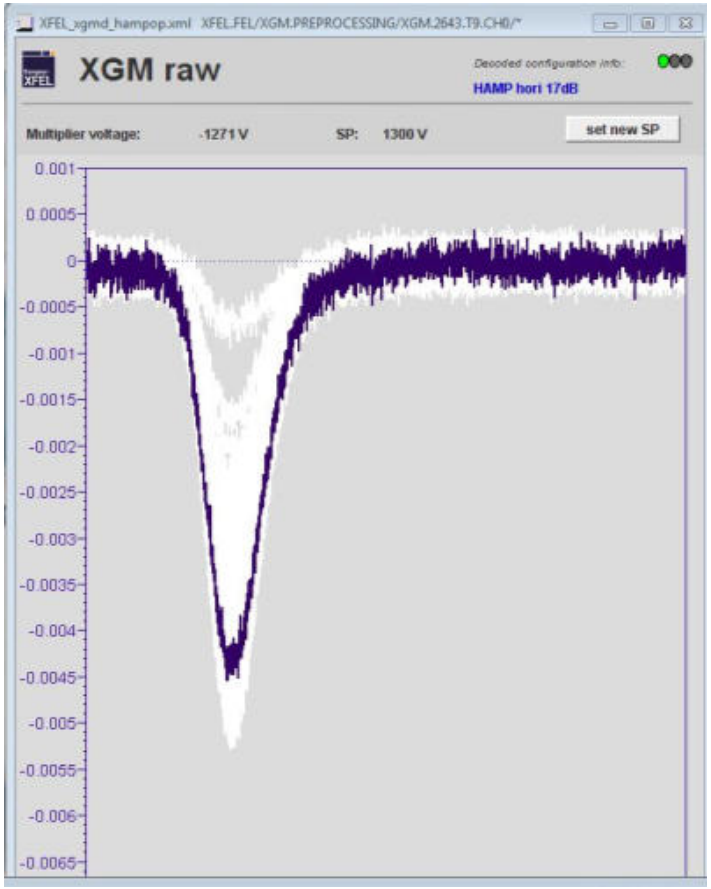
Less intensity at XTD9 because beam was split to FXE / SPB

640µJ
at 1.5A / 8.27keV
24h delivery
(July 2017)

24.07.2017 20:12

Typical operation of the pulse resolved and highly sensitive XGM-detector HAMP

(here: single bunch mode)



Single bunch mode

Xe at 5E-5 mbar

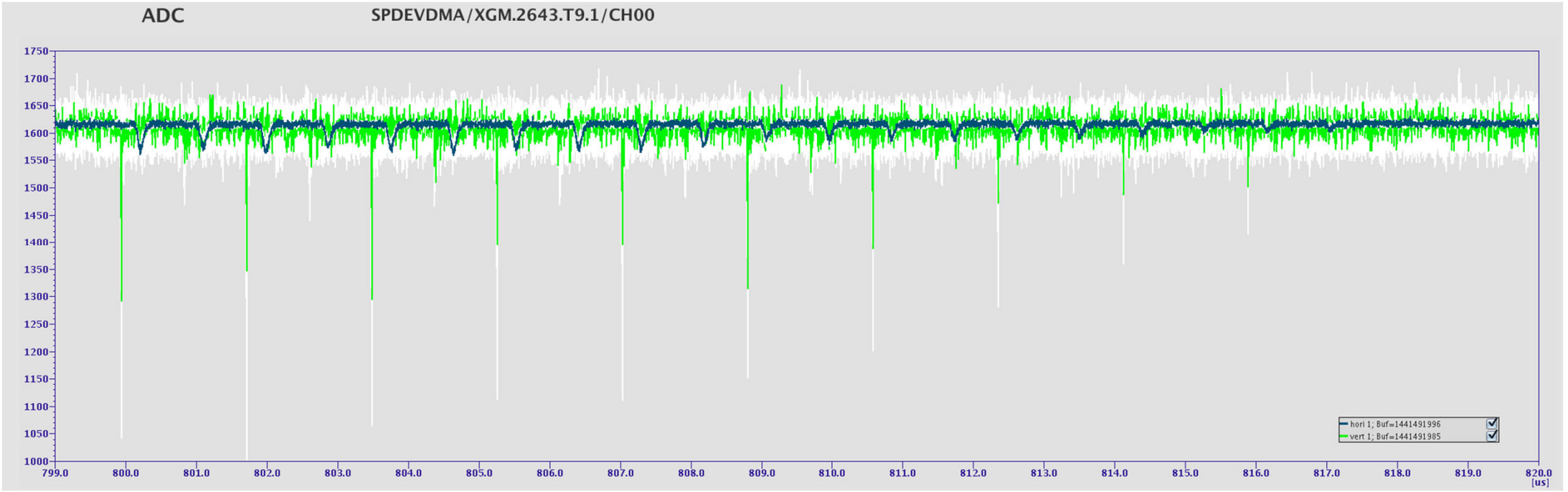
479µJ at 1.5A / 8.27keV

Can detect already spontaneous radiation

Main applications of HAMPs:

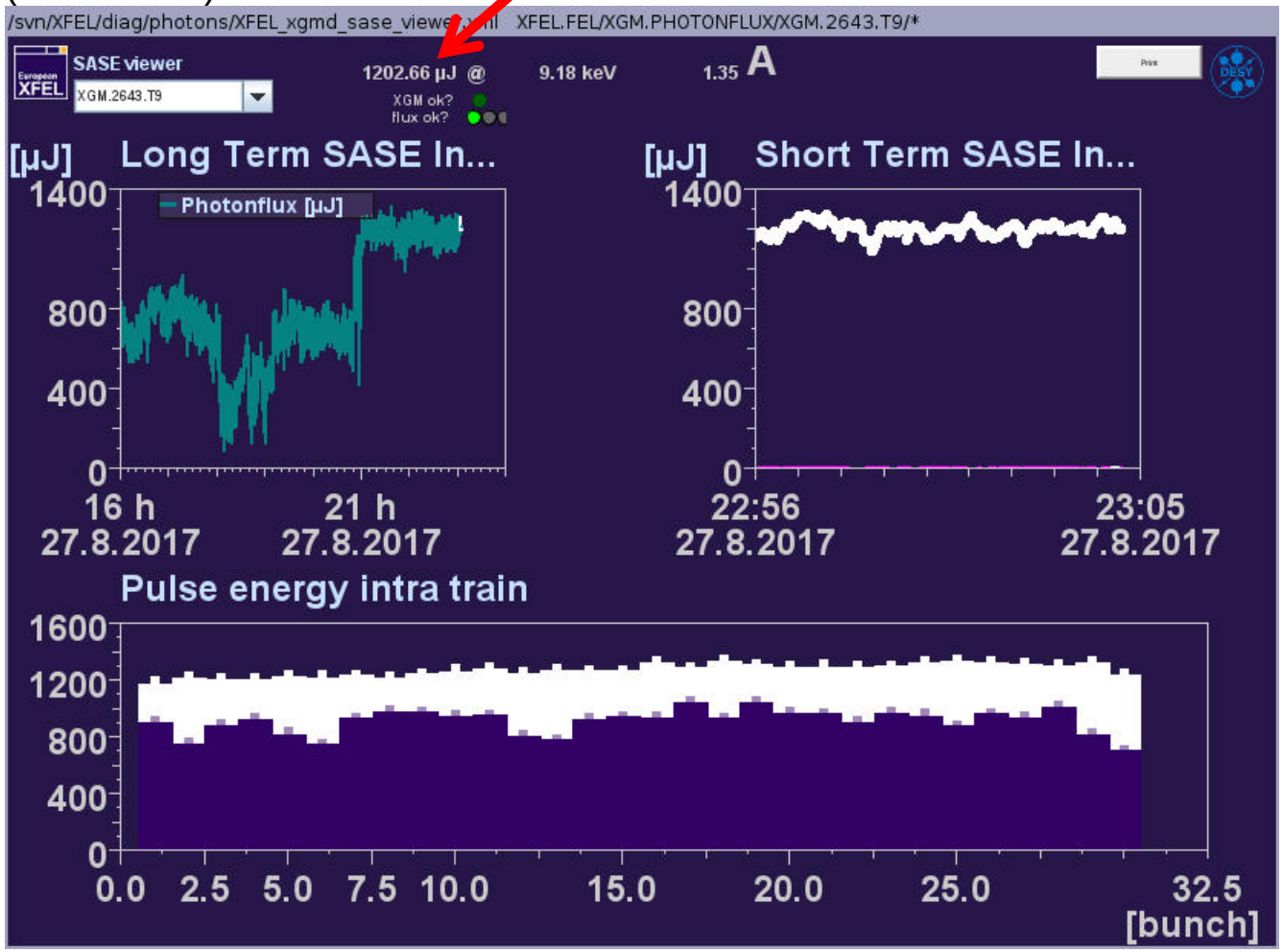
- Standard tuning tool for operators for Tuning from spontaneous to SASE
- XGM operation at hard X-rays beyond 12keV

Ions (HAMP) and electrons (XGMD) at 1.12 MHz rep rate



Multibunch-mode

(30 bunches)



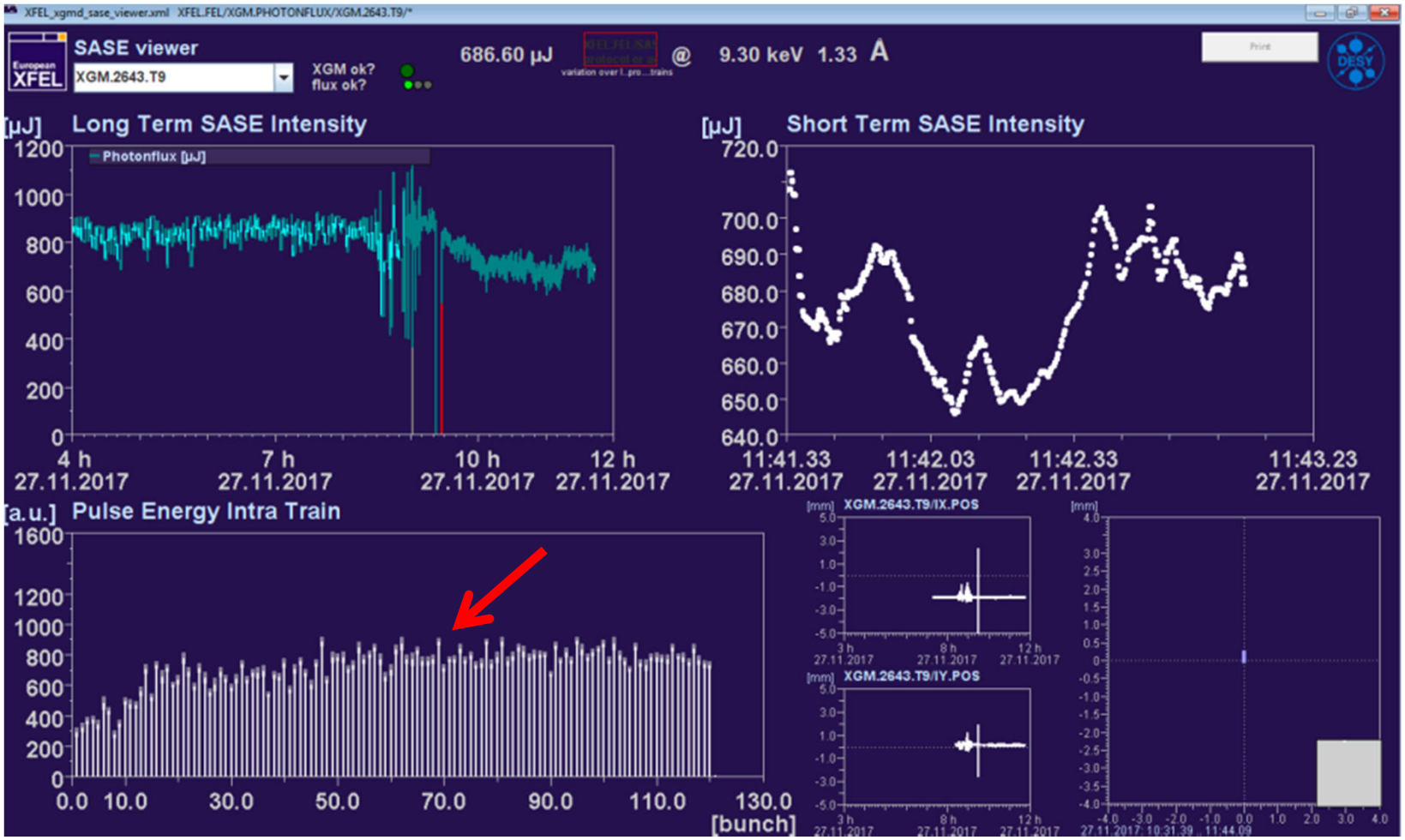
1200 µJ per pulse !!

30 pulses per train
10 trains per second
→ 360mW
at 1.35A / 9.18keV

27.08.2017 23:04

Multibunch-mode

(120 bunches)



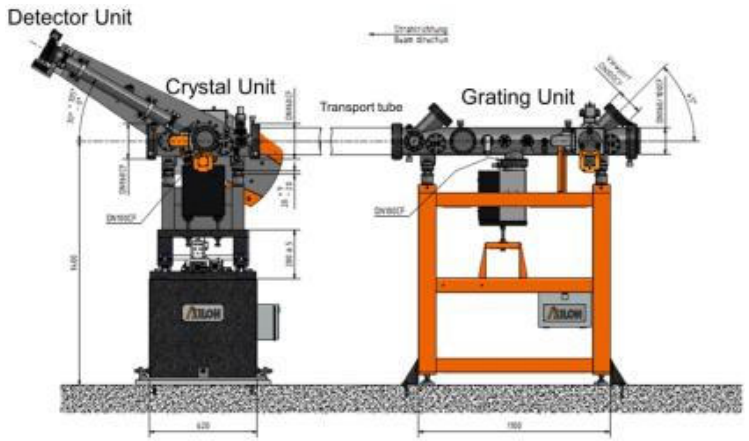
120 pulses per train !!

1200 pulses per second

almost 1 Watt

HIREX diagnostic spectrometer for SASE1

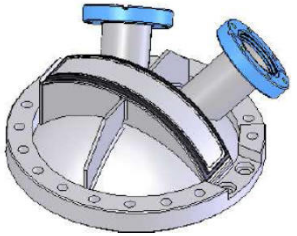
- Shot-to-shot spectral measuement
- Si(111) crystal + one grating commissioned
- Cross-calibration with FXE spectrometer at 8980eV
- Determined SASE bandwidth



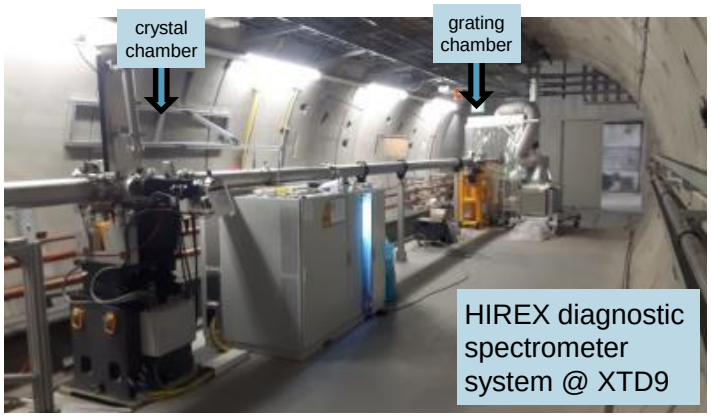
Ref.: N. Kujala / W.Freund, XPD

HIREX diagnostic spectrometer for SASE1

- Shot-to-shot spectral measuement
- Si(111) crystal + one grating commissioned
- Cross-calibration with FXE spectrometer at 8980eV
- Determined SASE bandwidth (20eV FWHM)



Be-window dome flange



HIREX diagnostic spectrometer system @ XTD9

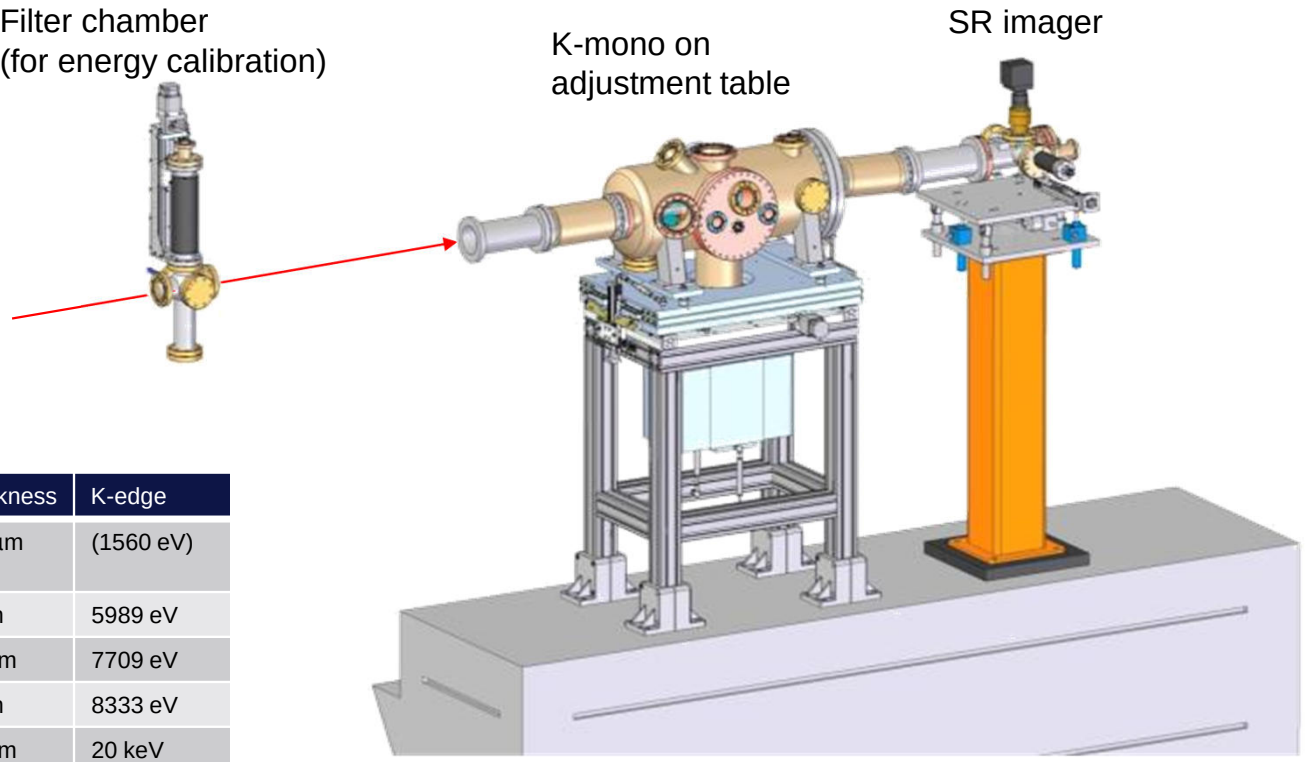
Ref.: N. Kujala / W.Freund, XPD

K-monochromator studies

Photon-based commissioning
of the undulators
using spontaneous radiation

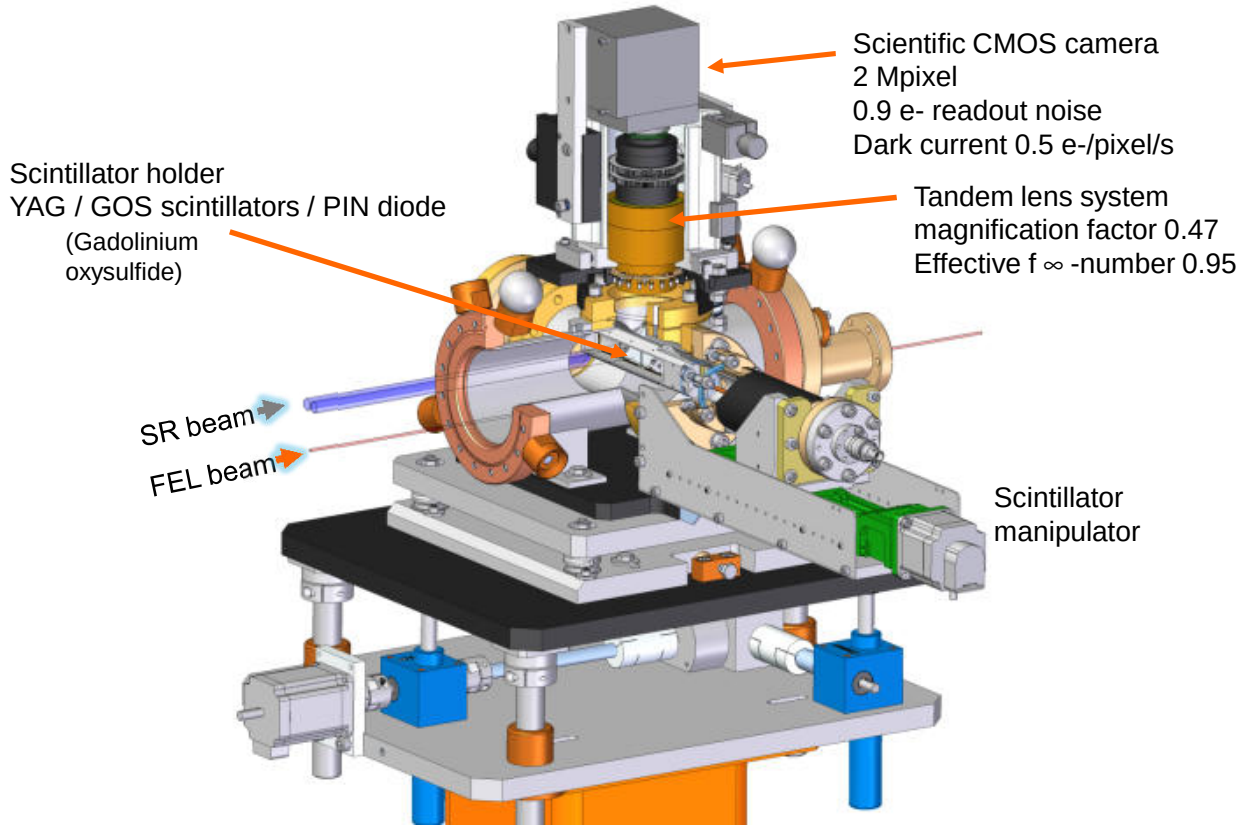
W.Freund, J.Liu, A.Koch, J.Grünert

K-Mono system



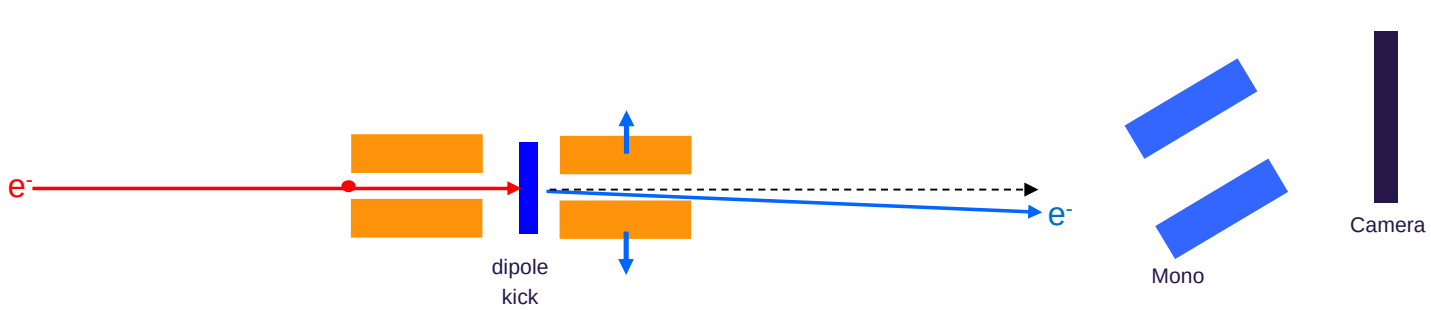
Material	Thickness	K-edge
Aluminum (light blocker)	2.5 µm	(1560 eV)
Chromium	5 µm	5989 eV
Copper	10 µm	7709 eV
Nickel	5 µm	8333 eV
Molybdenum	20 µm	20 keV

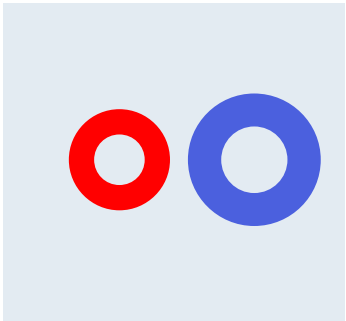
SR-Imager



CAD model of the SR imager

Kick electrons and image SR



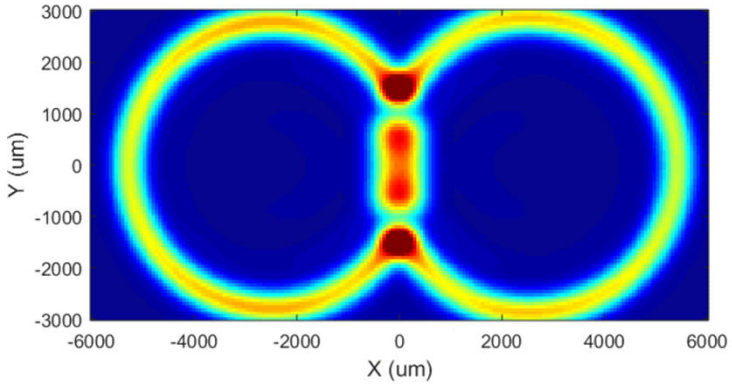


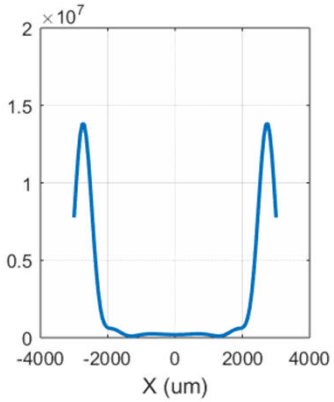
Pairwise undulator segment tuning “with kick”

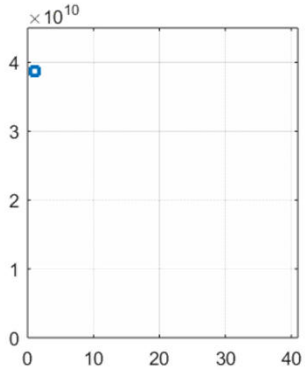
Takashi Tanaka, *Undulator Commissioning Strategy for SPring-8 XFEL,* Poster, FEL09

Simulation

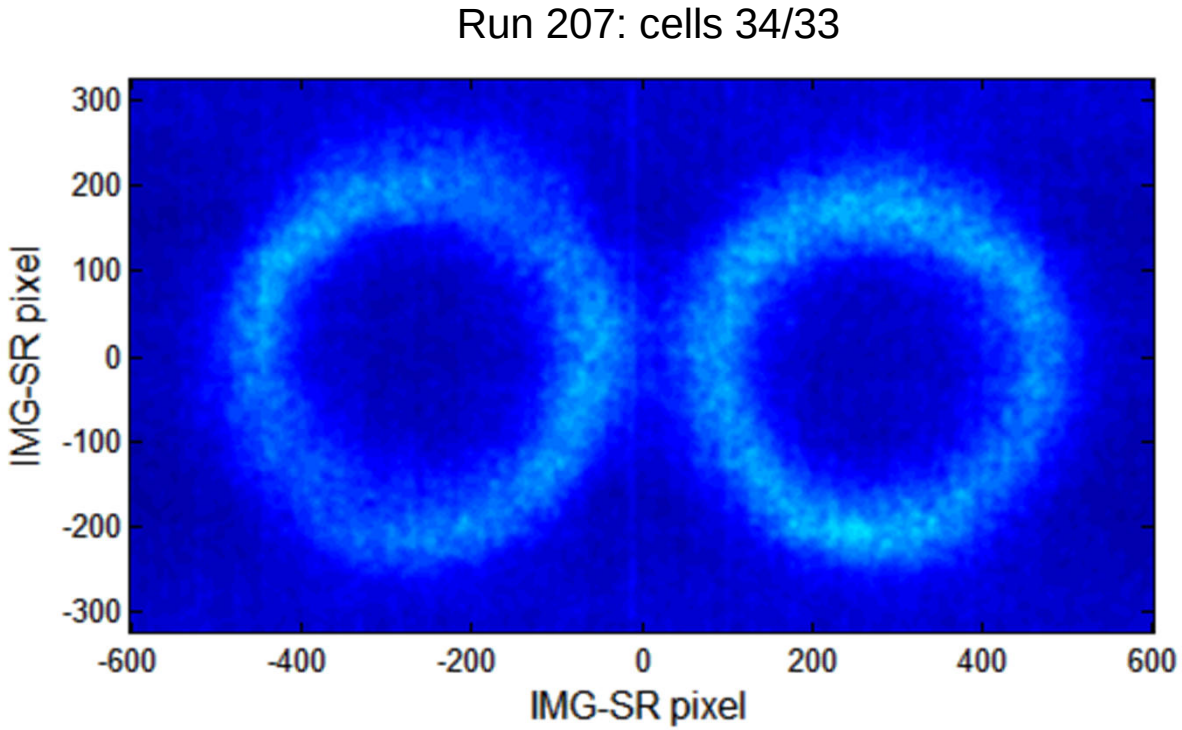
- Simulation of kick method (14.32GeV / 8.1keV)
- Simulation data calculated by W.Freund
  using SPECTRA 10.1.0 (T.Tanaka / H.Kitamura)







Bragg scan, two undulator segments closed

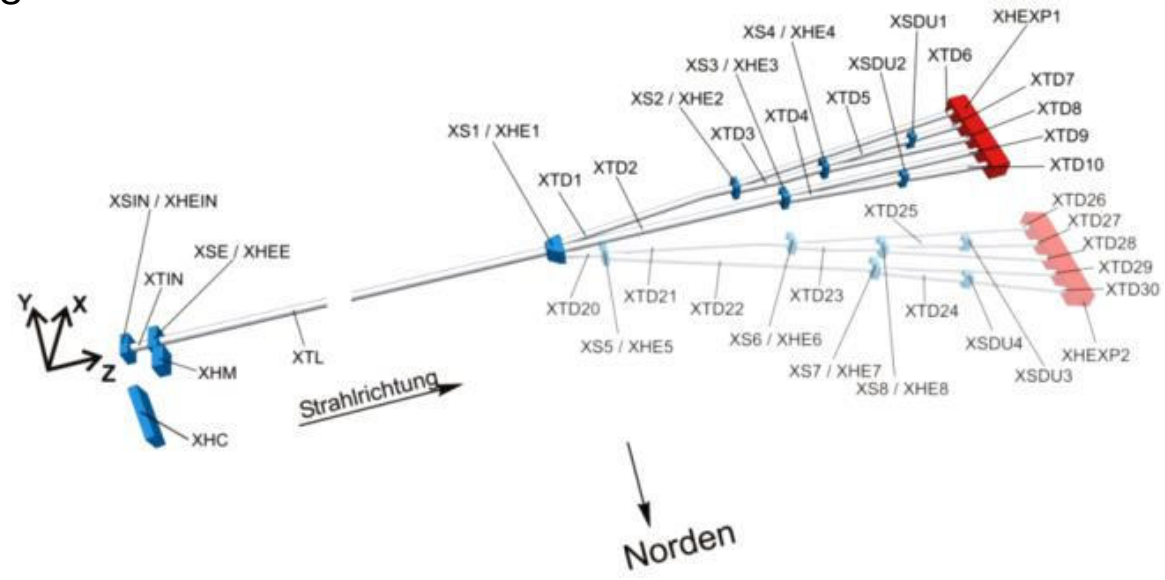


Summary

- Achievements
  - Commissioning of SASE1 photon system (May-Sep.2017) reached all goals for early user operation
  - Mirrors perform well (slope errors & stability), CRLs in XTD2 can focus beam in 2D over 600 m
  - Online Diagnostics and Imagers are reliable workhorses (24/7 since months)
  - Advanced diagnostics such as HIREX is operating
  - Special studies started (K-mono, Gain Studies)
  - First User Run was successfully completed

Teaser – what's coming up (2018 and beyond)

- More SASE1 (FXE, SPB/SFX) Early User Experiments
  - 2nd call, allocation May to June 2018
- SASE2 and SASE3
  - First lasing
  - Early User Experiments starting end of 2018
- Upgrades / European XFEL II
  - Fill empty tunnels (SASE4+5)
  - Second fan of tunnels
  - „cw" operation (beyond bursts)

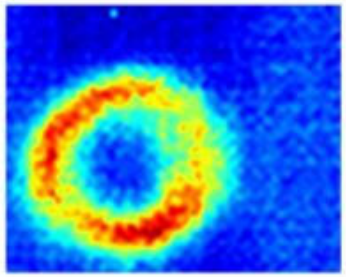


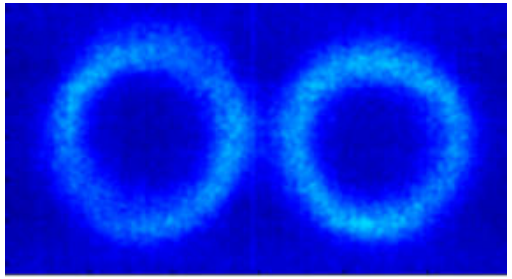
Acknowledgements

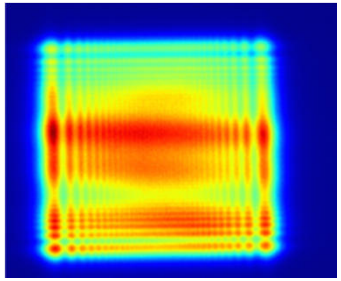
- European XFEL groups

  XPD, XRO, VAC, AE, CAS, ITDM, UNSYS, photon commissioning team / experiment groups

- DESY accelerator run coordinators and BKR operators
- External contributors (Diagnostics)
  - XGM: K.Tiedtke group (DESY), Dräger company
  - MCP: E. Syresin, O.Brovko, A.Grebentsov (JINR, Russia)
  - KMONO: A. Erko (HZB), J. Rehanek (PSI)
  - HIREX: C.David, M. Makita, B.Schmitt (PSI), AXILON
  - Imagers: JJ X-ray, Irelec, FMB-Berlin
- LCLS colleagues (Y.Feng, J.Krzywinski, Z.Huang,…)







PhotonDiag 2018

Please reserve the date: **September 17-19, 2018**

www.fels-of-europe.eu/PhotonDiag2018

Welcome to the European XFEL user facility.
Thank you for your attention.