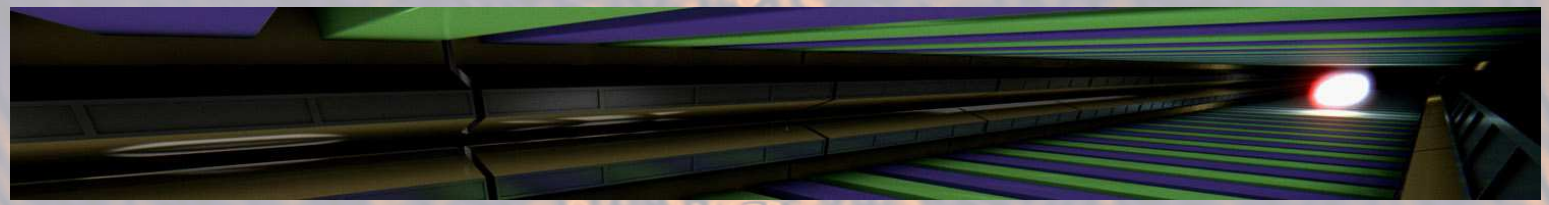


Calibration Working Group and Calibration Infrastructure

Jola Sztuk-Dambietz (XFEL)

on behalf of

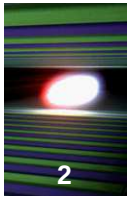
the European XFEL Calibration Group

May, 26th 2014

16th Meeting of the XFEL Detector Advisory Committee

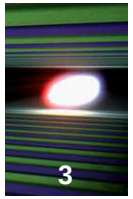
European XFEL GmbH, Hamburg

Outline



- Introduction
- Update on detector calibration activities at the XFEL
- Infrastructure for detector calibration and tests at the XFEL – status and plans
- Summary

Calibration Strategy – where calibration will be done



XFEL.EU Project Phase	Detector Laboratory	FELs/Synchrotrons/ Particle Accelerators		
		External Sources	XFEL. EU	
			Instr. Hutches	Dedicated beam
Start-up	Initial detailed calib. and characterization of det. prototypes, modules	Response of detector vs. either rep. rate or intensity		
Commissio-ning	Initial detailed calib. and characterization of full systems	**Calibration of 1MPix 2D cameras is NOT feasible due to the demanding infrastructure requirements**	• Cross-check lab. calibration • Characterization of the detector response under real conditions (rep.rate and intensity)	
User Operation	Calibration of the full system only if necessary (accident, detailed detector response investigation, etc..)		**Scientific. exp:** Part of regular exp. procedure (shall take a few mins) **Maintainance time** - Calibration/tests using in-hutch sources	Detailed detector response investigation under real conditions (rep.rate and intensity)

Detectors in Experimental Hutch

- Work on definition of calibration procedure during operation phase is ongoing
- Discussion with instrument scientists
  - Required accuracy for calibration parameters
  - Specific online monitoring in addition to „standard“ detector performance monitors
  - Calibration data which can/should be taken as part of an experimental campaign/run
  - Detector alignment
  - X-ray calibration sources within the hutches → agreed with the instrument scientists

Detector Calibration & Characterization Priorities

Parameter	Priority	Target Accuracy
Conversion gain ***G*(x,y)**	**High**	**< Poisson statistic**
Dark signal ***O*(cell nr,x,y)**	**High**	**< detector noise**
Noise ***N*(x,y)**	**High**	**< 1%**
Bad pixel ***B*(cell nr,x,y)**	**High**	
Quantum efficiency ***QE***	**High**	**5-10 % (simulation uncertainty)**
Dynamic range ***DR*(x,y)**	**High**	**< Poisson statistic**
Memory cell droop (signal losses) ***MD*(cell nr, x,y)**	**High**	**< detector noise**
Charge transfer inefficiency ***CTI*(x,y)**	**High**	**< 1%**
Point spread function ***PSF*(x,y)**	**Low**	**to be defined**
Line spread function ***LSF*(x,y)**	**Low**	**to be defined**
Spectral response	**Medium**	**< 10%**
Flat field corrections	**High**	**< 10%**
Common mode	**High**	**to be defined**
Event splitting	**High**	**to be defined, for low rate applications**
Alignment (position calibration)	**High**	**< pixel size**

Measurement

Simulation

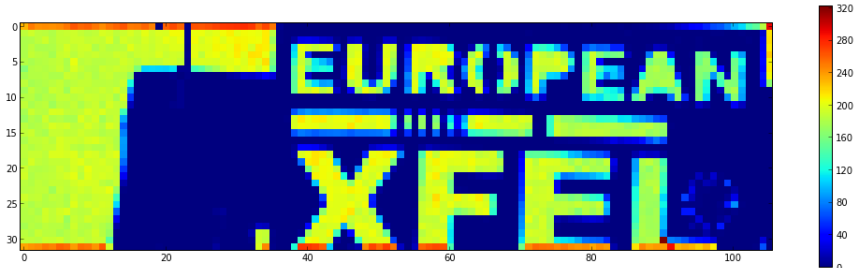
Algorithm/ reconstruction

Required (motivated by science) accuracy for calibration parameters → input from scientific groups is needed

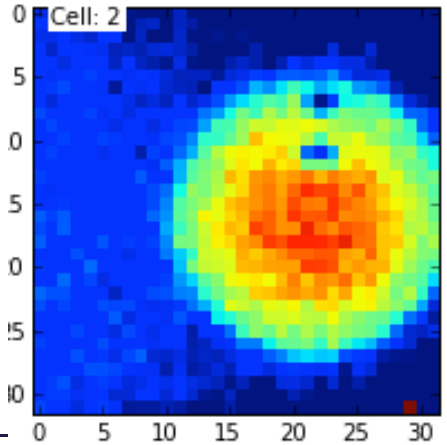
Calibration Software in use (S. Hauf)

- Calibration software developed in the group is successfully being used in real cases
- **Karabo pipeline:** LPD calibration data analysis → data taken at beamline (PETRAIII) and in WP-75 laboratories
- **Stand-alone pipeline**: FastCCD characterization (MSc thesis of F. Kasnar)

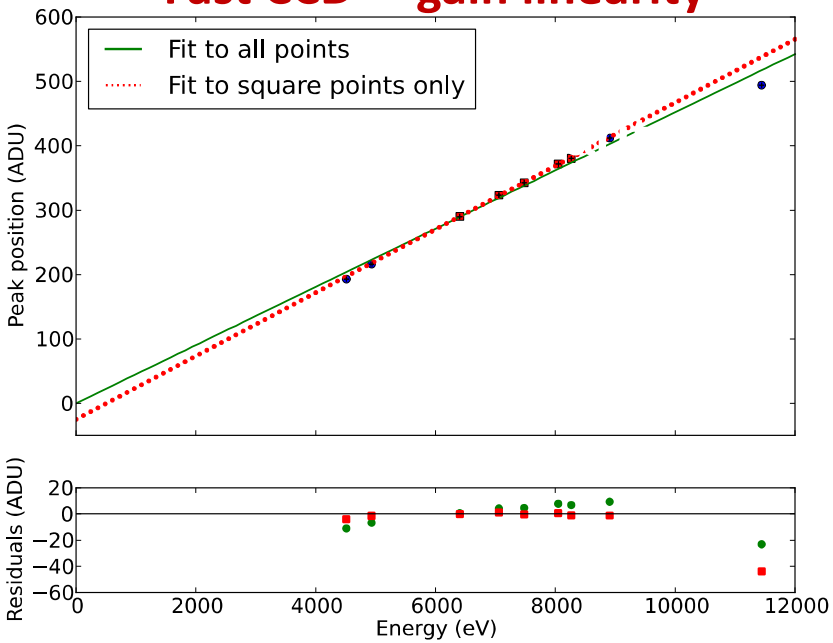
LPD prototype at PETRA III

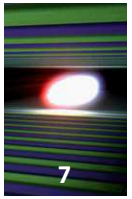


LPD prototype in WP-75 laboratory



Fast CCD – gain linearity





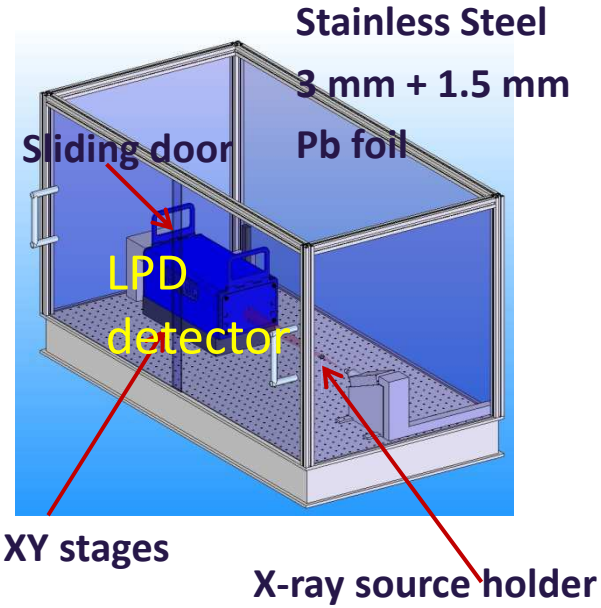
Status of Laboratory Calibration Infrastructure

Portable Detector X-ray Test Stand – Little Amber

Test and calibration of detector prototypes at ambient conditions

Status since the last XDAC:

- **Operational with Fe-55 source (A=1.85 GBq)**
- Shielding installed (3mm SS + 1.5 mm Pb) → sufficient for low-and medium-power X-ray tubes
- Temp. increase in the setup during operation of LPD prototype → Ventilation system was installed



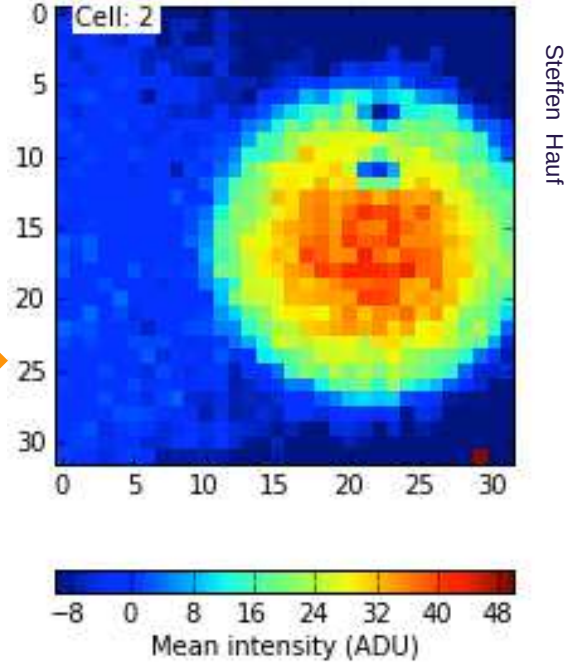
Next Steps:

- Extension with low-power X-ray tube
  - Interlock system installation ongoing
  - All necessary documentation was provided → TÜV approval within the next few weeks
- Installation of XY stages + PLC system

→ Operational since February 2014

Little Amber – First X-rays at XFEL.EU ☺

First X-ray image at the XFEL.EU with LPD two-tile system



Measurement conditions

- Source Fe-55 (1.85 GBq)
- 4.5 MHz rep rate (detector)
- 4 cycle integration time
- Average of 2000 pictures

Fe-55 Multi-Purpose Vacuum Test Setup - PHEOBE

Modular flexible device for multipurpose usage (filters, pin-holes, collimator, etc..)

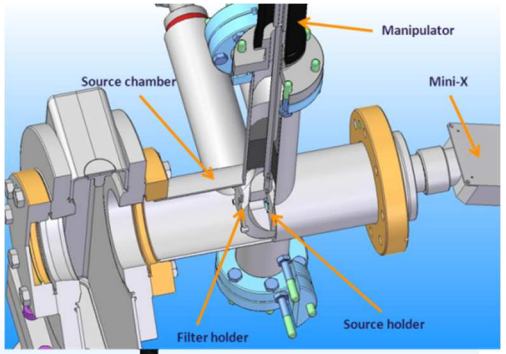
Status since the last XDAC :

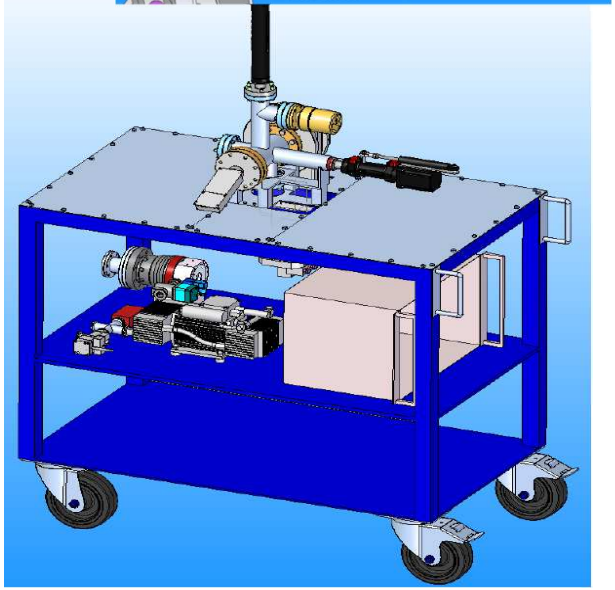
- PLC system ready (vacuum system, manipulators)
- Safety and operation manual ready
- **Operational** as soon as radioactive source is available

  → **end of June 2014**
- Cart designed and in the production stage

Next steps:

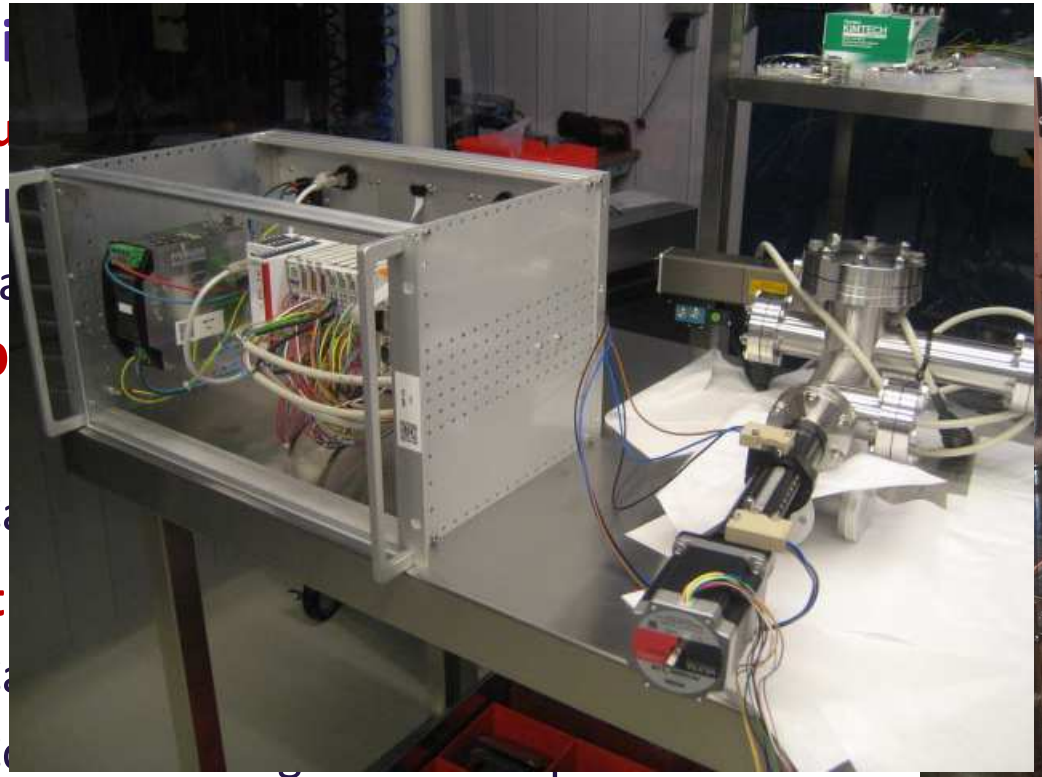
- Cart assembly
- Commissioning of the setup
- First use-case: pnCCD detector
- Extension of the system with portable X-ray tube
- 2nd system to be built for FastCCD

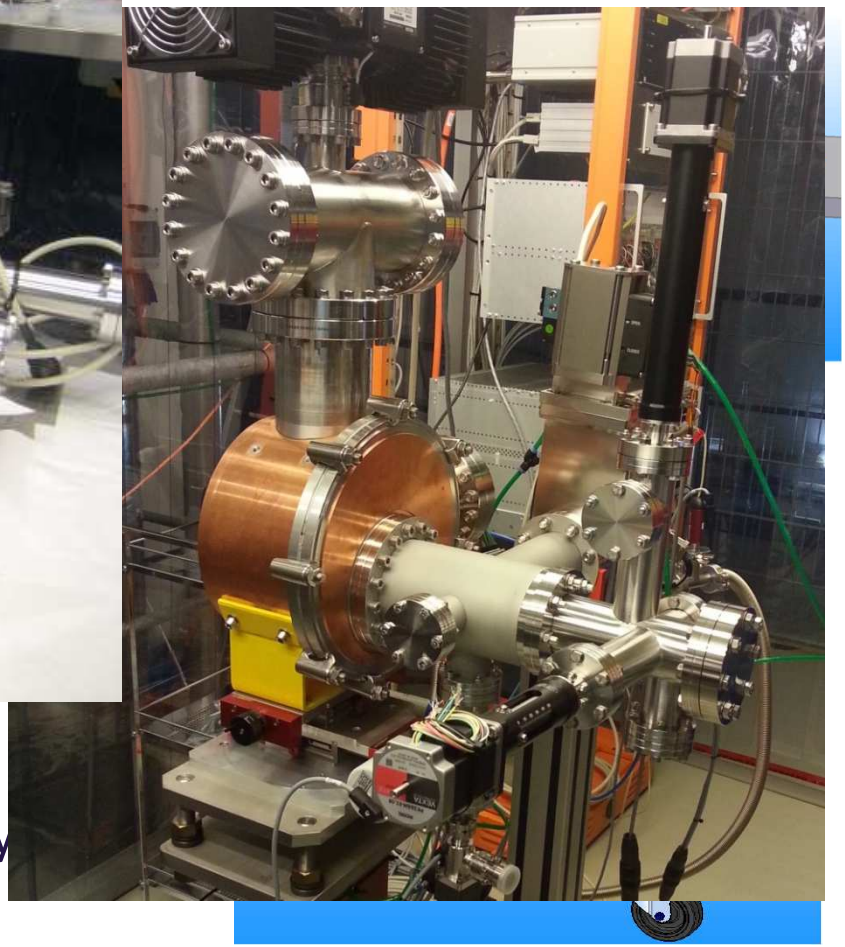




Fe-55 Multi-Purpose Vacuum Test Setup - PHEOBE

Modular flexible device for multipurpose usage (filters, pin-holes, colli





Statu

- Pl
- Sa
- **O**

→

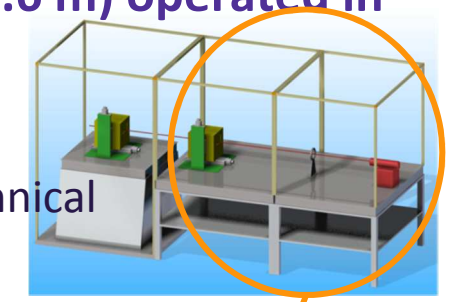
- Ca

Next

- Ca
- Ce
- First use-case: pnCCD detector
- Extension of the system with portable X-ray
- 2nd system to be built for fastCCD

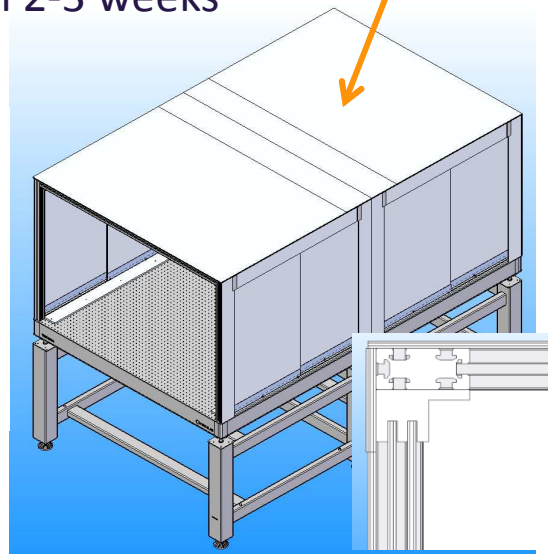
Ambient X-ray Test Setup for ¼ Mpix Detectors – Big Amber

Modular setup for large and small area detectors (1.5 x 2.0 x 3.6 m) operated in dry air or N_2 atmosphere with high power X-ray tube (2 kW)



Status since the last XDAC:

- Progress from the conceptual design to the technical design → technical drawing for first two modules finalized
- X-ray tubes ordered→ Cu (8 keV), Mo (17.5 keV) tubes from Seifert
- Shielding plates Al-Pb-Al (2-3-2 mm) machined and delivered
- Support structure (tables, profiles, etc..) shall be delivered in 2-3 weeks
- Interlock system defined and agreed with Safety Group



Next steps:

- Assemble the first two modules
- Install interlock system
- TÜV approval
- Commissioning of the X-ray tubes
- Finalize design of the third module and tube support

→ Operational Q3 2014 for detector systems up to ¼ Mpx

Pulsed Multi-target X-ray Test Setup - PulXar

PANTER X-ray source as a testbed towards a pulsed sources

(Collaboration with PANTER X-ray test facility of the Max-Planck Inst. for extraterrestrial Physics)

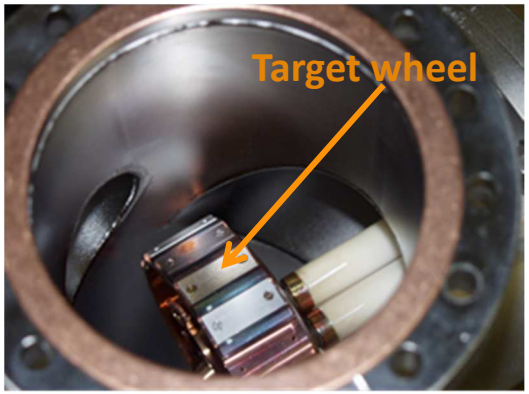
Status since the last XDAC:

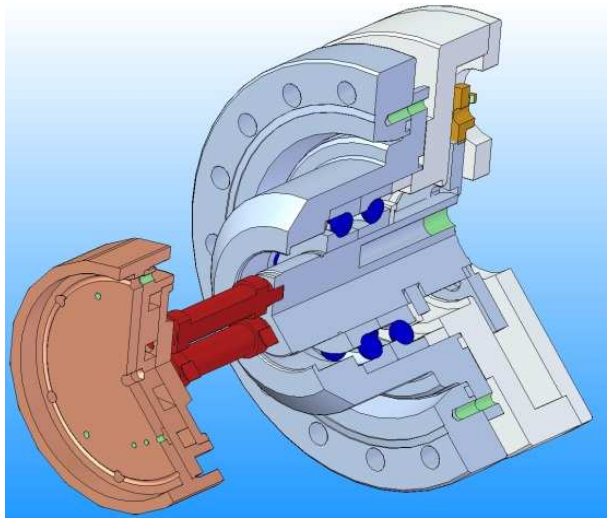
- Technical drawing of the PANTER multi-target X-ray tube implemented in our CAD system → work on optimization of the design is ongoing
- Copy of the PANTER X-ray source delivered to XFEL.EU
- Vacuum system components (pumps, gauges, valves, etc..) in house → vacuum system + control system will be a copy of the PHEOBE setup
- Power supplies delivered and successfully integrated in Karabo
- First successful vacuum tests ($p \leq 10^{-7}$ mbar)
- Support for the tube and filter wheel defined and components ordered

Pulsed Multi-target X-ray Test Setup - PulXar

Next steps:

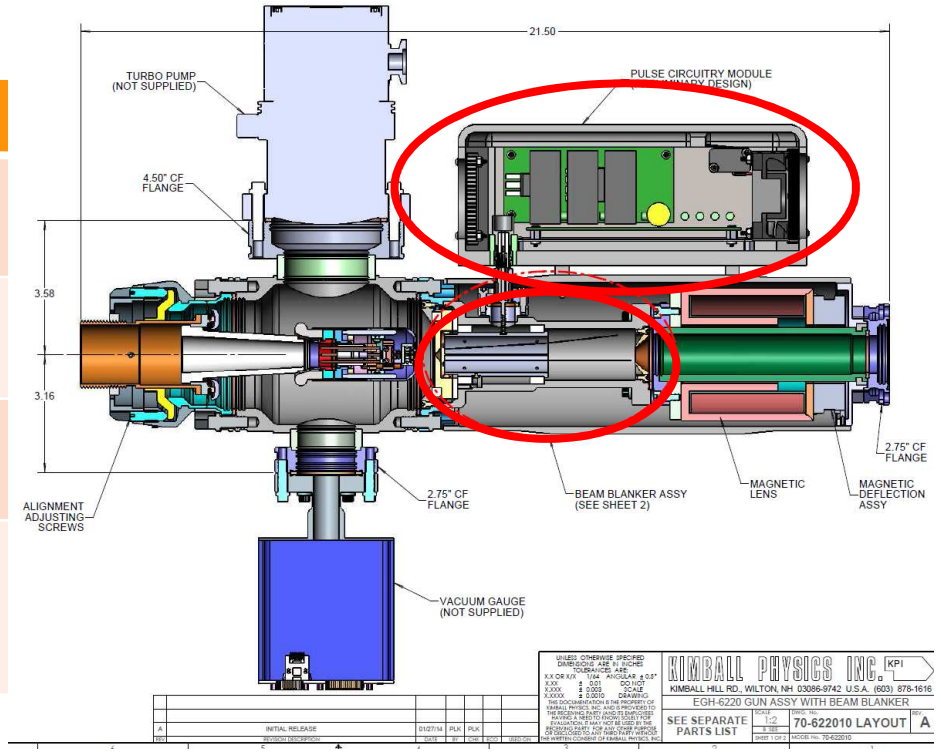
- Assembly of the support and pumping system including control system
- Reference detector setup to be ordered (SDD) → solution has been identified
- Commissioning of the PANTER tube
- Finish optimization of the mechanics →
  to be adapted to Kimball electron gun
- Produce a new tube vessel + target wheel
- Assemble with Kimball electron gun
- Interpret, test and commission Kimball e- gun





Kimball Physics Electron Gun for PulXar

Parameter	Pulsed mode	DC mode
Electron energy	1 - 50 keV	1- 60 keV
Electron beam current	10μA - 20 mA	10μA – 6mA
Beam diameter	0.15 – 10 mm	0.1-10 mm
Pulsed beam parameters	- Length: τ = 50 -150 ns rise: 2 ns / fall: 3-4 ns - XFEL burst mode	n.a.

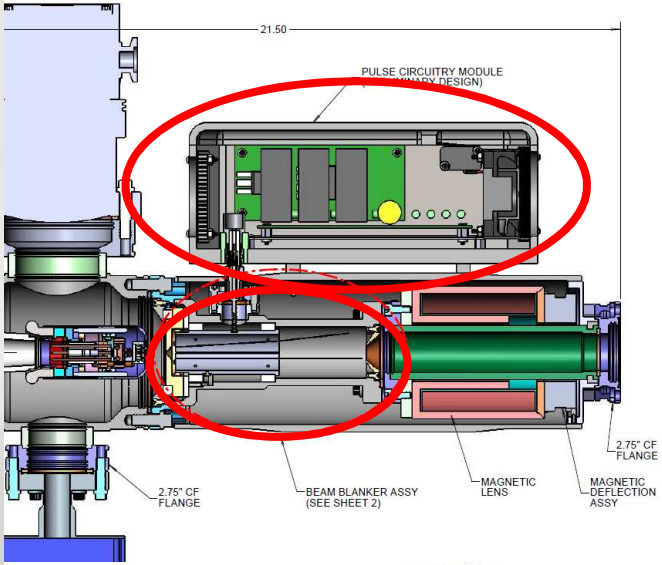


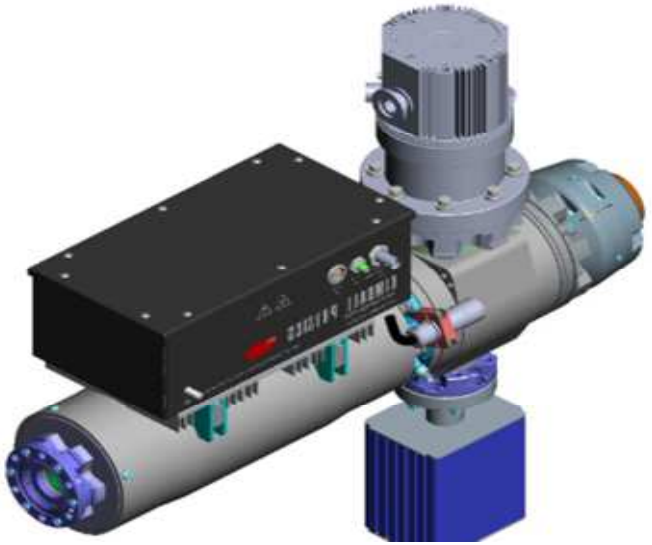
Status since the last XDAC:

- Custom beam blanker for high speed pulsing up to 5MHz designed and produced → 25 ns pulses are achievable
- Custom pulse generator with burst operation designed and produced
- Electron gun is in the testing phase → performance within the specification
- Expected delivery date: June 2014 (on schedule)

European XFEL

Kimball Physics Electron Gun for PulXar

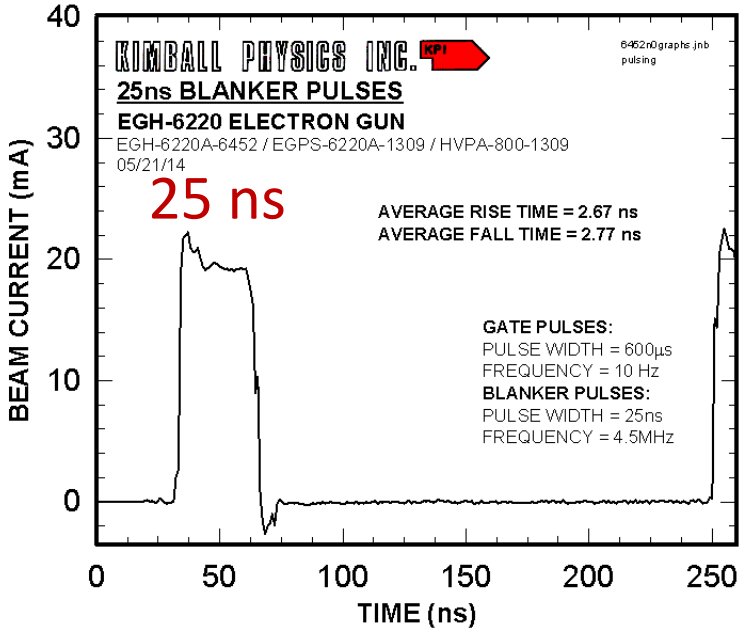


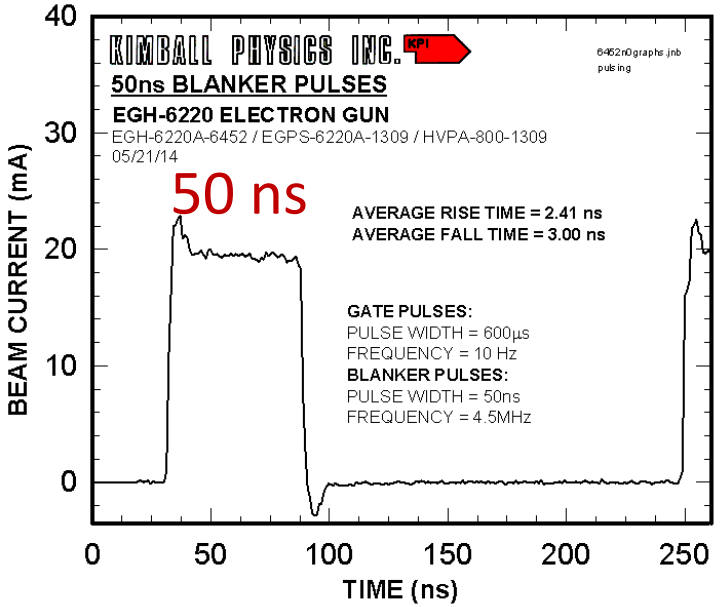


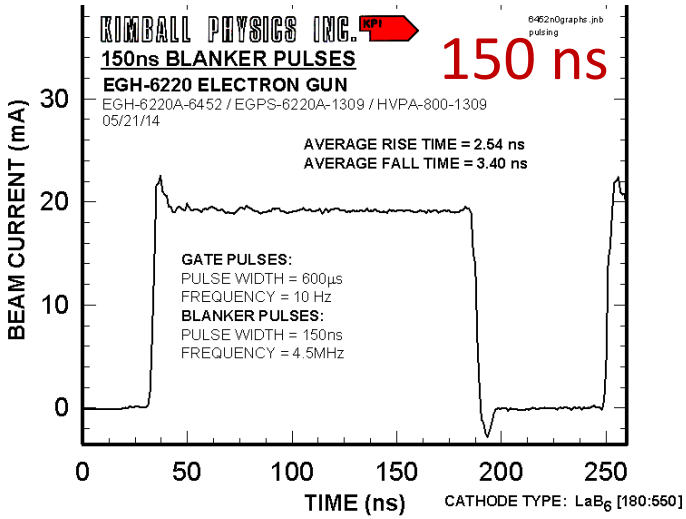
pulses are achievable

- Custom pulse generator with burst operation designed ar
- Electron gun is in the testing phase → performance with
- Expected delivery date: June 2014 (on schedule)

Electron Gun for PulXar – first test results

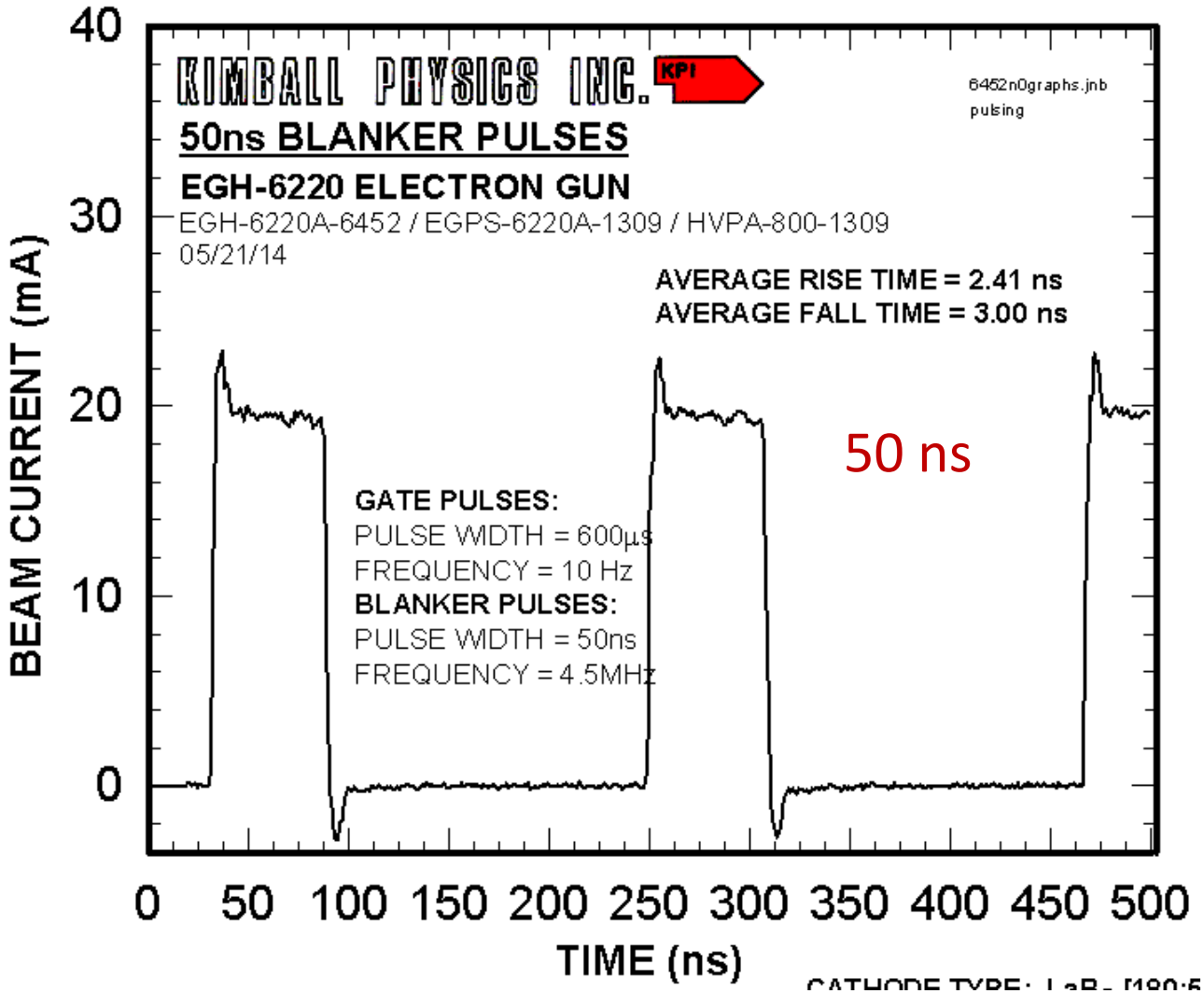






- Oscilloscope measuring the electron beam into the lab Faraday cup
- Blanker pulses 25, 50, 150 ns
- Electron energy Ee=50 keV
- Gun pressure p=2x10^{-8} mbar
- Rise/fall time 2.5-3.5 ns

Electron Gun for PulXar – first test results

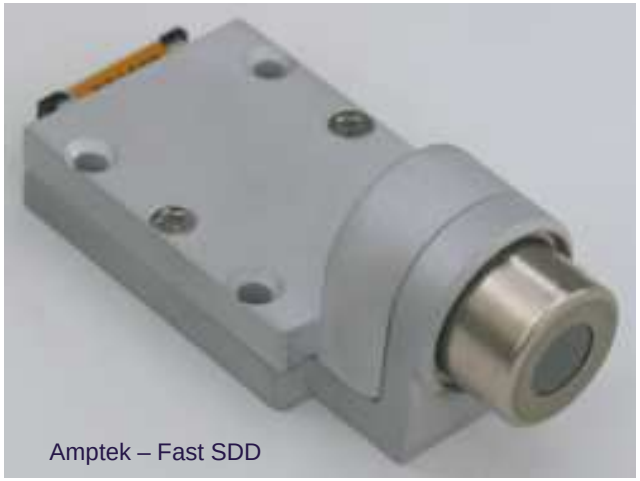


Reference detector for characterization of X-ray sources

- Reference detector for characterization of the **spectral** and **spatial distribution** of X-rays emitted by different X-ray sources
- Requirements:

Parameter	Value
Energy range	0.2-25 keV
Energy resolution	~160 eV @ 6keV
Count rate	> 10^5 cps
Thickness of Si	500 µm
Sensitive area	~ cm^2
Vacuum operation	Yes, 10^{-6} mbar
Readout system	synchronized to the pulsed X-ray source

- SDD + collimator/pin hole + movement system



- 160 eV FWHM resolution @ 5.9 keV and 100ns peaking time
- Peak-to-Background Ratio 20,000:1
- High Count Rate capability > 10^6 cps
- 25 mm^2 X 500 µm

European XFEL

Summary

- Construction and commissioning of calibration infrastructure is progressing well
- All source technologies are in use and operated in different laboratories → expect no show-stoppers during approval, but clear procedure for purchasing and approval for X-ray tubes shall be defined by the Safety Group → dedicated document in preparation
- Calibration Infrastructure – schedule:
  - First laboratory X-ray detector test setups Little Amber and PHEOBE operational (small prototypes)
  - Ambient X-ray Test Setup for ¼ Mpix detectors operational (up to ¼ Mpix) Q3 2014
  - Pulsed Multi-Target X-ray Test Setup operational (up to 1 Mpix) Q2 2015
- First implementation of calibration software in Karabo exists and is used for PETRAIII testbeam and in our laboratory
- First fast detector prototype at the XFEL and more to come in 2014

Additional information including introductory & Backup Slides

The Goals of the Calibration

What is detector calibration?

Conversion of the detector signal (arbitrary units) to physical quantities after **all necessary corrections are applied**

Why calibrate detectors?

Well calibrated detector → precise measurement → high quality scientific results

The goal(s):

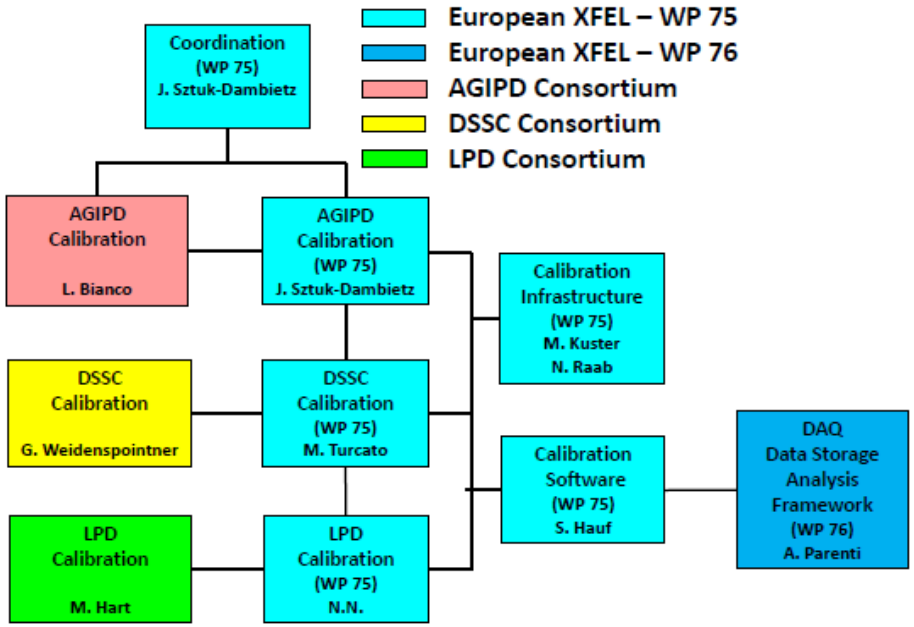
- Well calibrated & characterized detectors
- Well defined, standardized and user-friendly procedures and tools to obtain and apply calibration parameters to scientific data during user operation period

To achieve the calibration goals we need…

Step	Who	Status
Define detector parameters to be calibrated	Consortia, WP-75	✓
Define the required accuracy for the detector parameters to be calibrated	Scientific Instruments	
Develop strategies to calibrate occurring constants for the different types of detectors	Consortia, WP-75	✓
Calibration Infrastructure: • Define infrastructure and X-ray sources requirements • TDR of the infrastructure where necessary • Build the infrastructure	WP-75 WP-75 WP-75 & WP-76 (control system)	✓  
Define & develop calibration and test (re-calibration) procedures	WP-75 in cooperation with Scient. Instruments	
Define & implement calibration data format and structure	WP-76 in cooperation with WP-75	
Define and implement calibration data base	WP-76 in cooperation with WP-75	
Develop & implement calibration software in Karabo	Consortia, WP-75	
Calibration measurements	Consortia, WP-75	

Calibration Working Group

Responsible contact persons of the group:



- Work done by detector consortia, WP-75, WP-76
- Experts from consortia available beyond start-up phase of the project
- Involvement of beamline scientists becomes necessary

- **Meetings:** every 6 months → Last meeting May 2014
- Exchange information and discuss progress and open issues, define next steps
- Available documentation

Indico page with presentations and documents:
https://indico.desy.de/categoryDisplay.py?categId=278
Calibration Working Group site @ Alfresco -
https://docs.xfel.eu/share/page/site/calibration/dashboard

Outlook

- Proposal for parameters to be calibrated or characterized exists
- Responsibilities were defined
- Open questions to be addressed by the Consortia and XFEL

→ how precise the calibration needs to be done (input from instruments necessary) ←→ definition of methodology/tools ←→ how precise the calibration can be done for each of the parameters

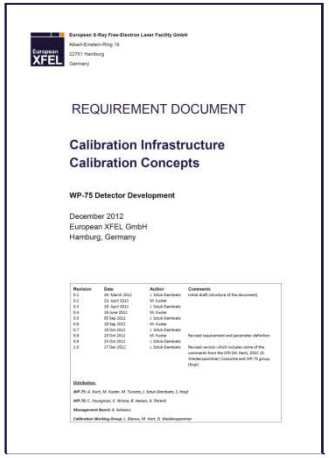
→ definition of priorities

Example:

1 - gain conversion, noise, bad pixels, droop

2- quantum efficiency

3 – split events?



European X-Ray Free-Electron Laser Facility GmbH
Albert-Einstein-Ring 19
22761 Hamburg
Germany

REQUIREMENT DOCUMENT

Calibration Infrastructure
Calibration Concepts

WP-75 Detector Development

December 2012
European XFEL GmbH
Hamburg, Germany

Table 1: List of performance parameters to be calibrated or characterized for the different kind of detector technologies, which will be used at the European XFEL facility.

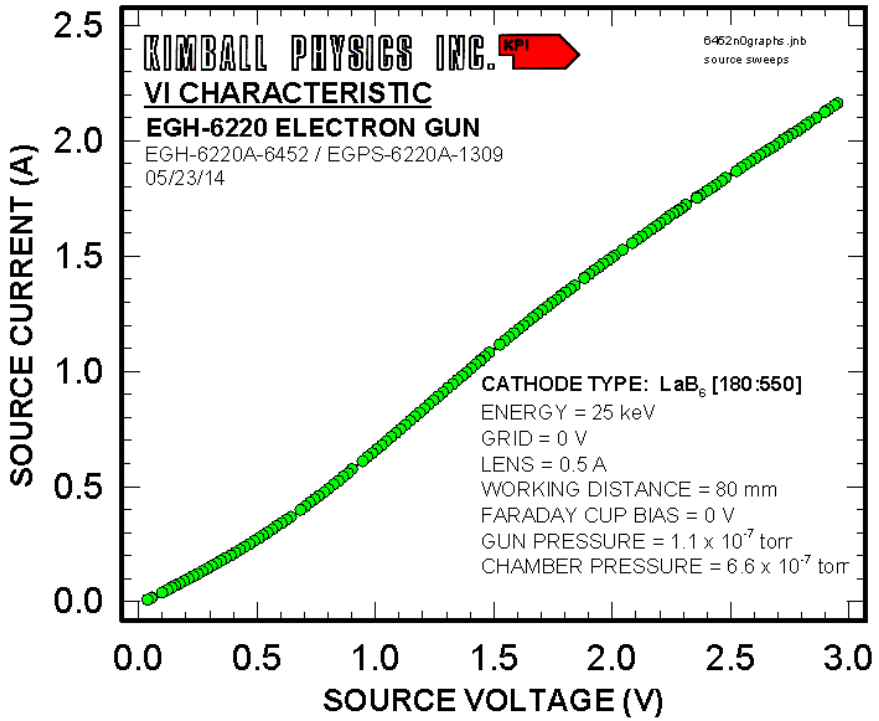
Parameter	AGIPD	DSSC	LPD	CCDs (10 Hz)	Strip Detectors	Point Detectors
Conversion gain ***G*(x,y)**						
RARC(readout channel)						
Dark signal ***O*(x,y)**						
Noise ***N*(x,y)**						
Bad pixel ***B*(cell nr,x,y)**						
Quantum efficiency ***QE***						
Detective quantum efficiency ***DQE***						
Dynamic range ***DR*(x,y)**						
Pile-up						
Memory cell droop (signal losses) ***MD*(cell nr, x,y)**					depends on the detector final specification	
Charge transfer inefficiency ***CTI*(x,y)**						
Point spread function ***PSF*(x,y)**						
Line spread function ***LSF*(x,y)**						
Spectral response						depends on the detector

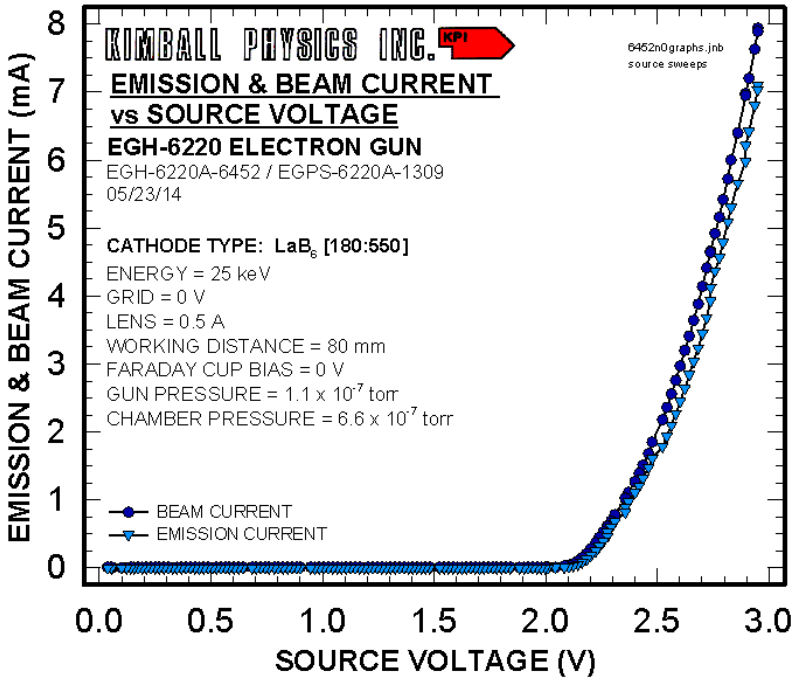
Calibration Strategy - what is needed to calibrate detectors

- Infrastructure to run detector (DAQ, data storage, data base, cooling, cabling etc..)
- Data analysis tools
- Different kind of stimulus (X-rays, charged particles, etc..)

Required	Parameter	Comments
Internal charge injection	Gain conversion, Memory Charge Looses (Droop)	Internal source needs to be cross calibrated with the real X-rays
Laboratory X-ray sources (isotopes, X-ray tubes)	Gain conversion, Detector Response Function, Flat-field, Charge Transfer Inefficiency, Quantum Efficiency	Measurements which do not require high intensity and XFEL timing structure at the same time
Beam from FELs/Synchrotrons/ Particle Accelerators	Flat-field, Splitting Events – Crosstalk	All measurements which require high intensity and appropriated XFEL timing

Electron Gun for PulXar – first test results

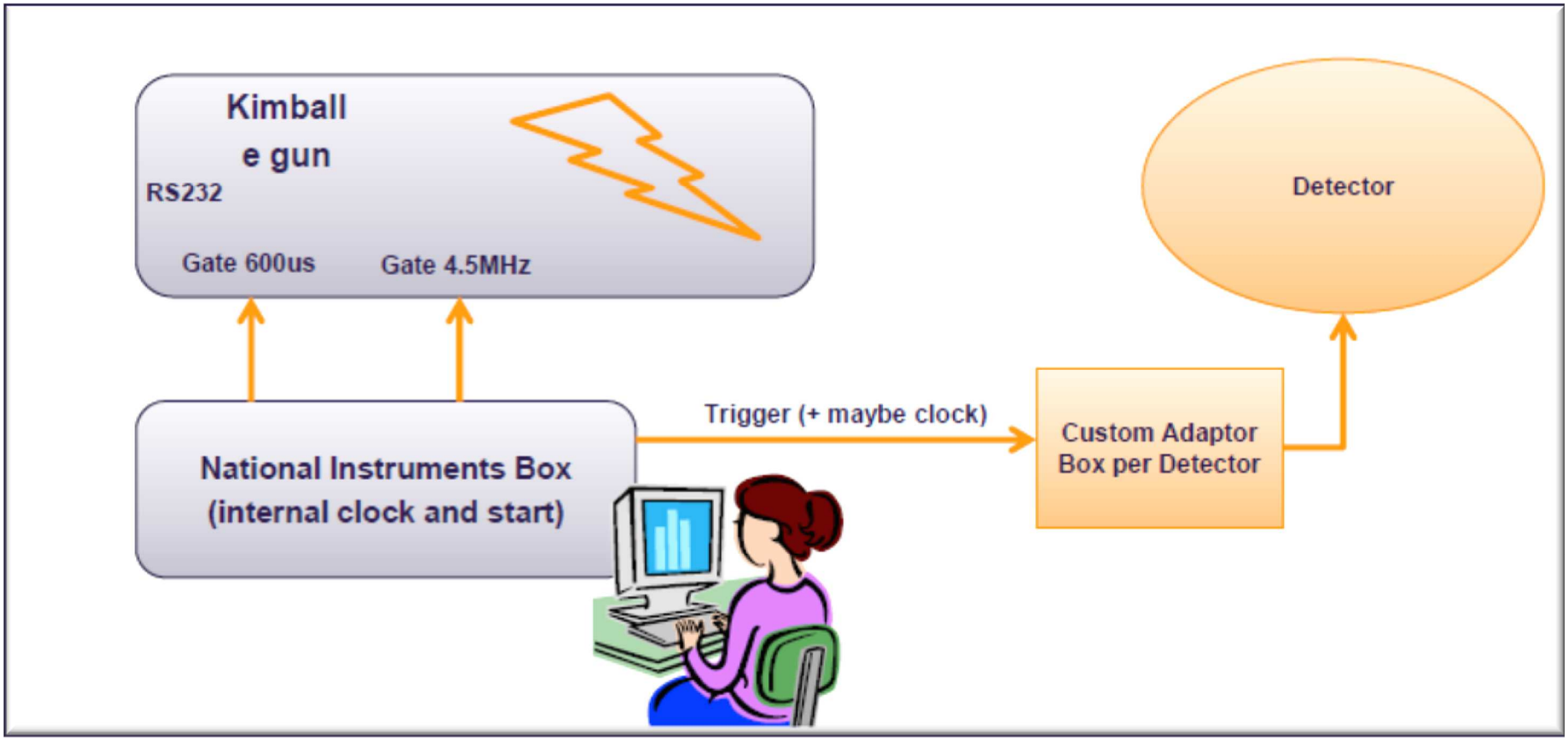




Multi-target Pulsed X-ray source

Clock and Control system (P. Gessler)

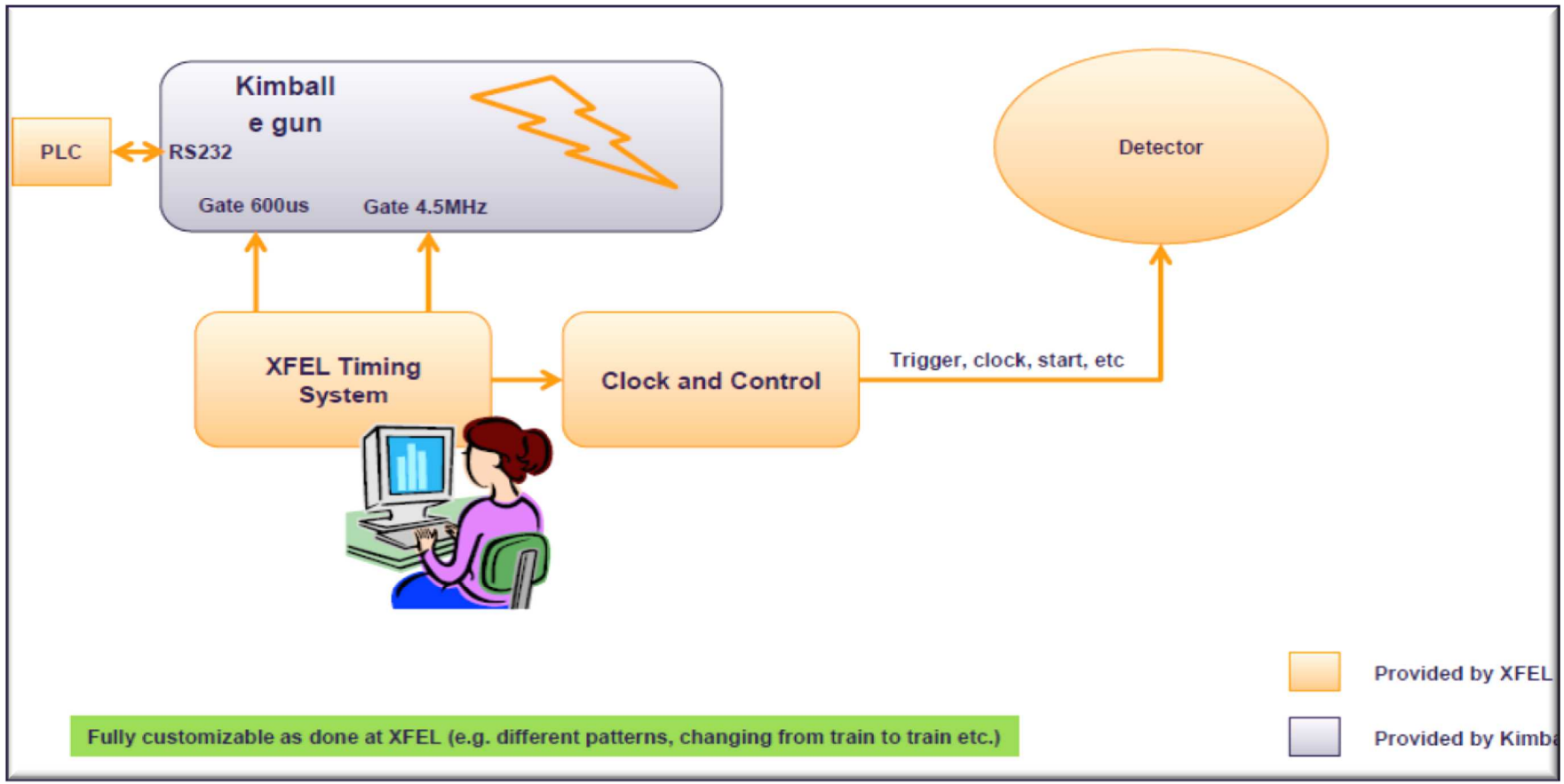
- Day one solution – detector “triggered” by the source



Multi-target Pulsed X-ray source

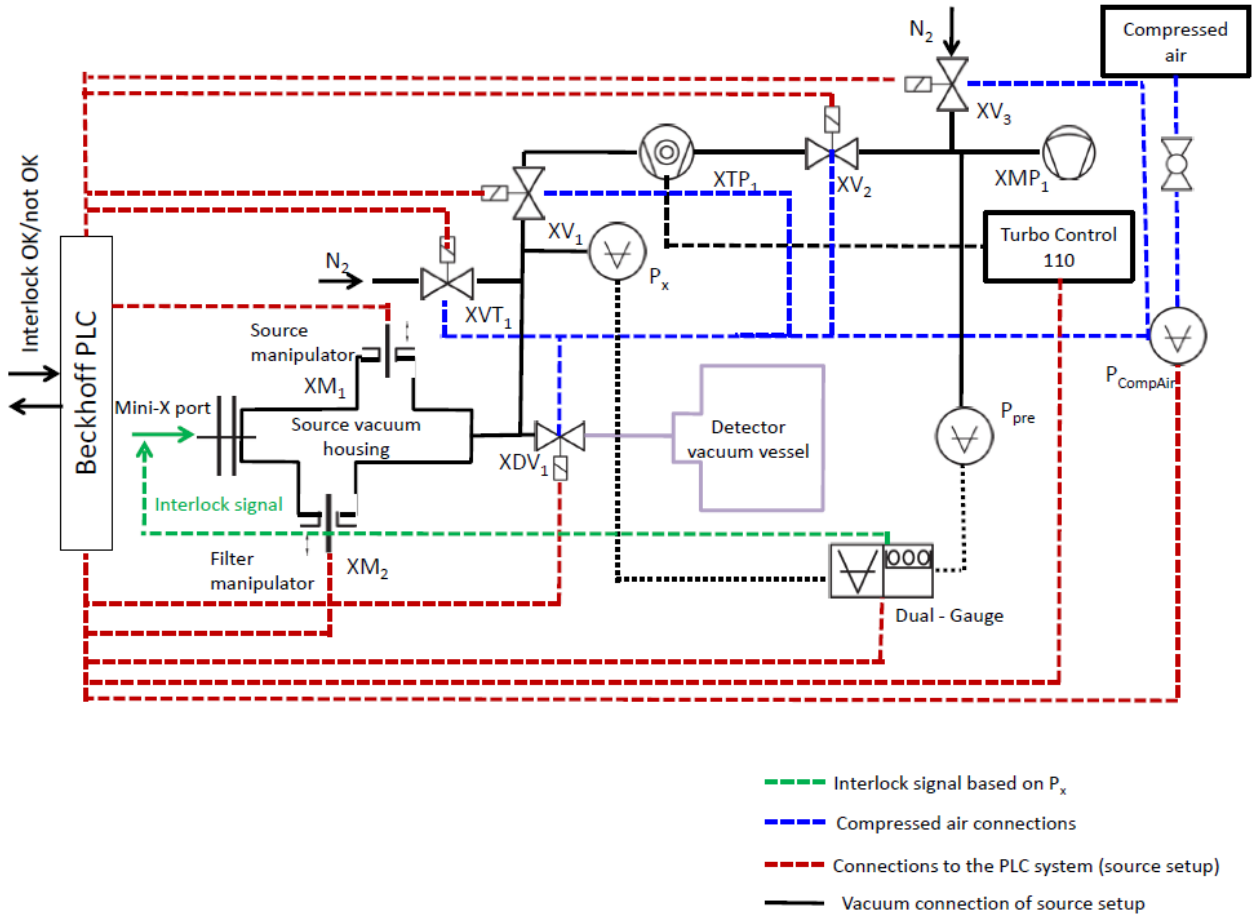
Clock and Control system (P. Gessler)

- Final solution – XFEL Timing system



Vacuum compatible X-ray setup

Vacuum system – fully controllable by Beckhoff PLC



Reference detector for characterization of X-ray sources - example system

- Reference detector for characterization of the **spectral** and **spatial distribution** of X-rays emitted by different X-ray sources