The European Cluster of Advanced Laser Light Sources

Graham Appleby – European XFEL

This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 654220

Overview

- Foundation and description of EUCALL
- EUCALL goals and objectives
- EUCALL Work Packages
- EUCALL Young Researcher Travel Bursaries
- Summary

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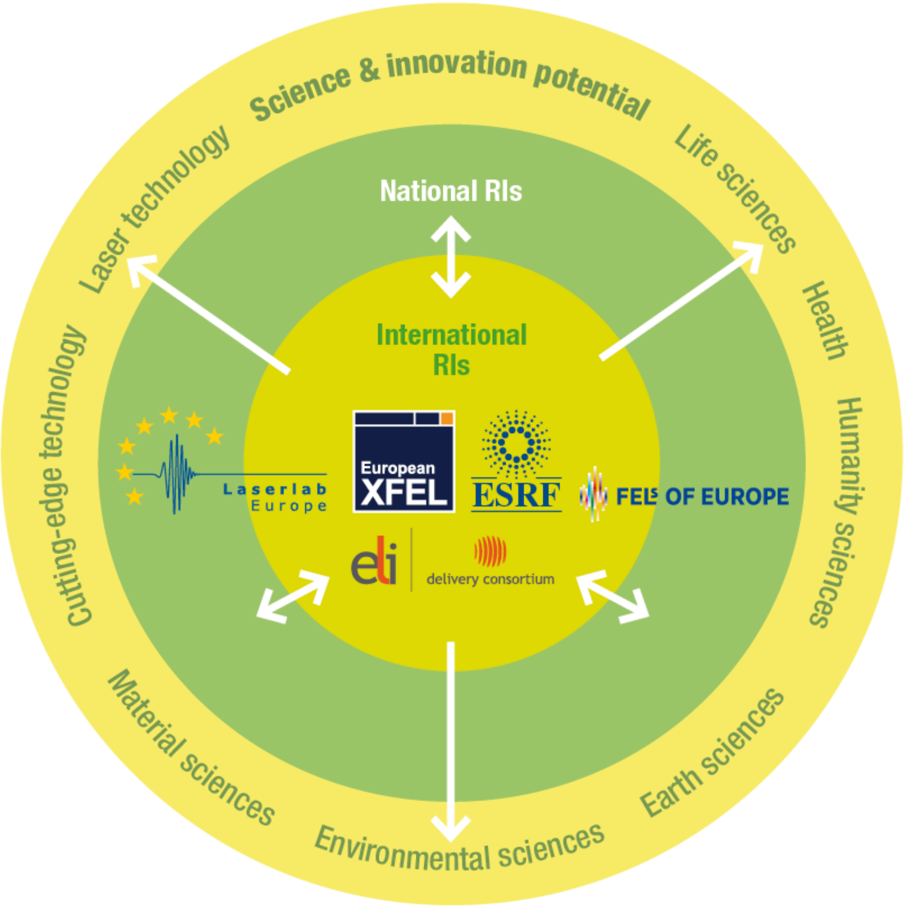
The situation (I)

- ESFRI photon-science projects
  - ELI
  - ESRF
  - European XFEL
- Networks
  - Laserlab-Europe (LLE)
  - FELs of Europe (FoE)
- National RIs



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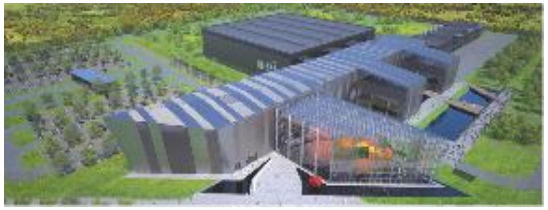
The situation (II)

- Accelerator-based RIs (SR, FEL)
  - Successful and large user program
  - Increasing complexity (OLs, FELs, …)
  - X-rays reach diffraction limit & non-linear regime
  - Optical laser methods applied
- Optical-laser based RIs (ELI, LLE faci.)
  - New and ramping up
  - New schemes to create X-rays
  - X-ray methods provided to users



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The situation (III)

SR RIs

FEL RIs

OL RIs

Low emittance electron accelerators

X-ray methods and techniques

User programs

Ultrafast and non-linear science

Optical laser methods

Optical laser (high energy, fs)

Data issues (volume, policies)

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The situation (IV)

SR RIs

FEL RIs

OL RIs

RIs to support scientific exploitation by users from multiple domains

Atomic & molecular sciences

Condensed-matter

Materials Sciences

Chemistry

Structural biology

Geo- & planetary science

Cultural heritage

Optical & high-field sciences

Medical applications

Medical applications

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Foundation of EUCALL

- Overlap between optical laser light sources and accelerator based X-ray light sources has been limited due to
  - different photon energies
  - different scientific applications
  - different character of the light source installations
- Optical lasers have become powerful enough to drive intense secondary sources of coherent and incoherent X-rays
  - new RIs for user access being developed
- X-ray FELs combine the properties of optical lasers with X-ray radiation, plus provide unprecedented X-ray brightness
- EUCALL formed to address the **emerging overlap of scientific applications** of laser and X-ray light sources

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European Cluster of Advanced Laser Light Sources

EUCALL is a network between large-scale user facilities for:

- Free electron laser (FEL) radiation
- synchrotron radiation
- optical laser radiation

Under EUCALL, they work together on:

- common methodologies and research opportunities
- tools to sustain this interaction in the future

Facts and figures:

- 7M€ from Horizon 2020 for project period 2015 - 2018
- 11 partners from nine countries, and two further clusters

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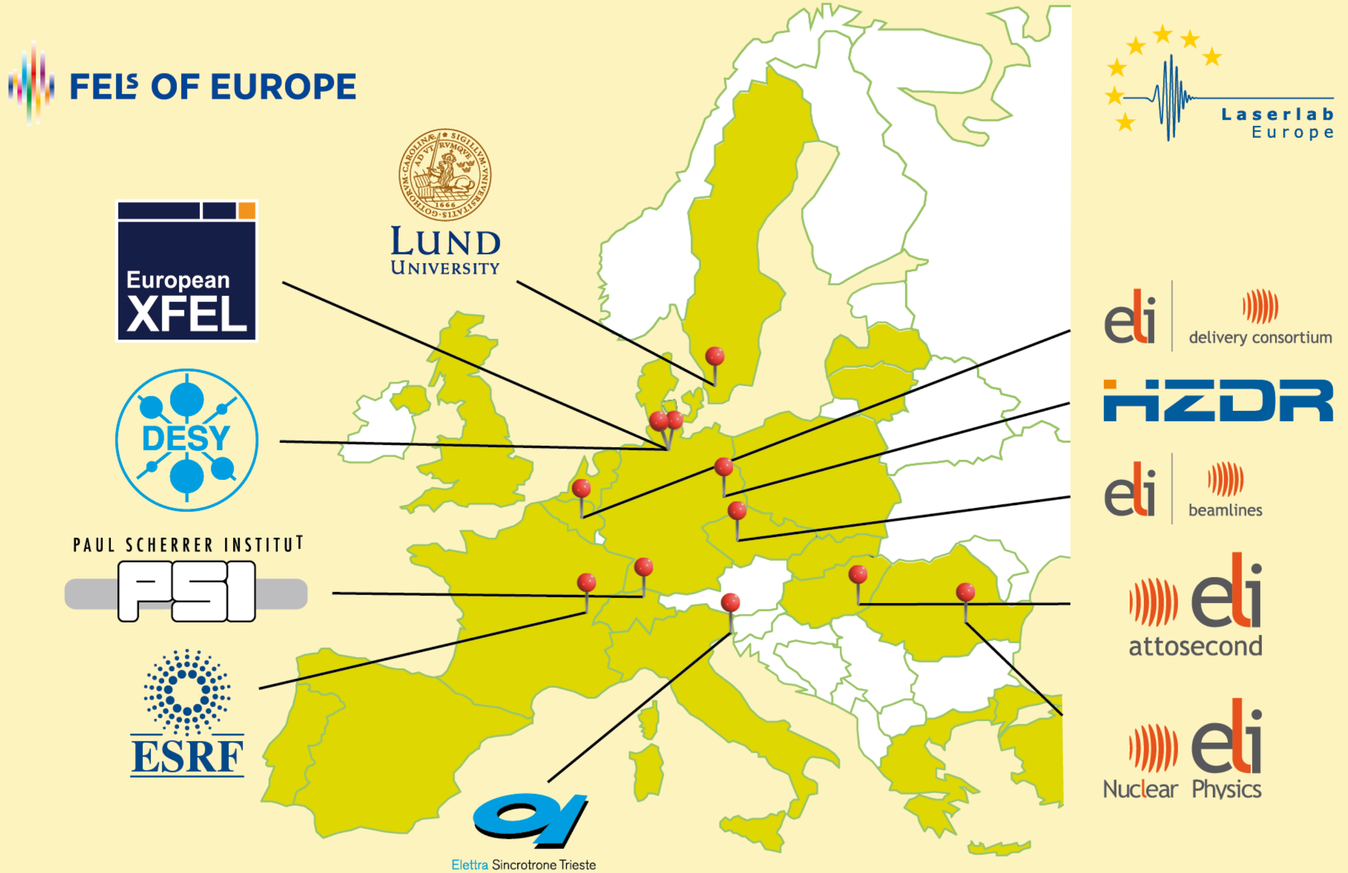
European Cluster of Advanced Laser Light Sources



EUCALL's six FEL and synchrotron sources and five optical light facilities (red pins). Countries involved in the European clusters FELs of Europe and Laserlab-Europe are coloured.

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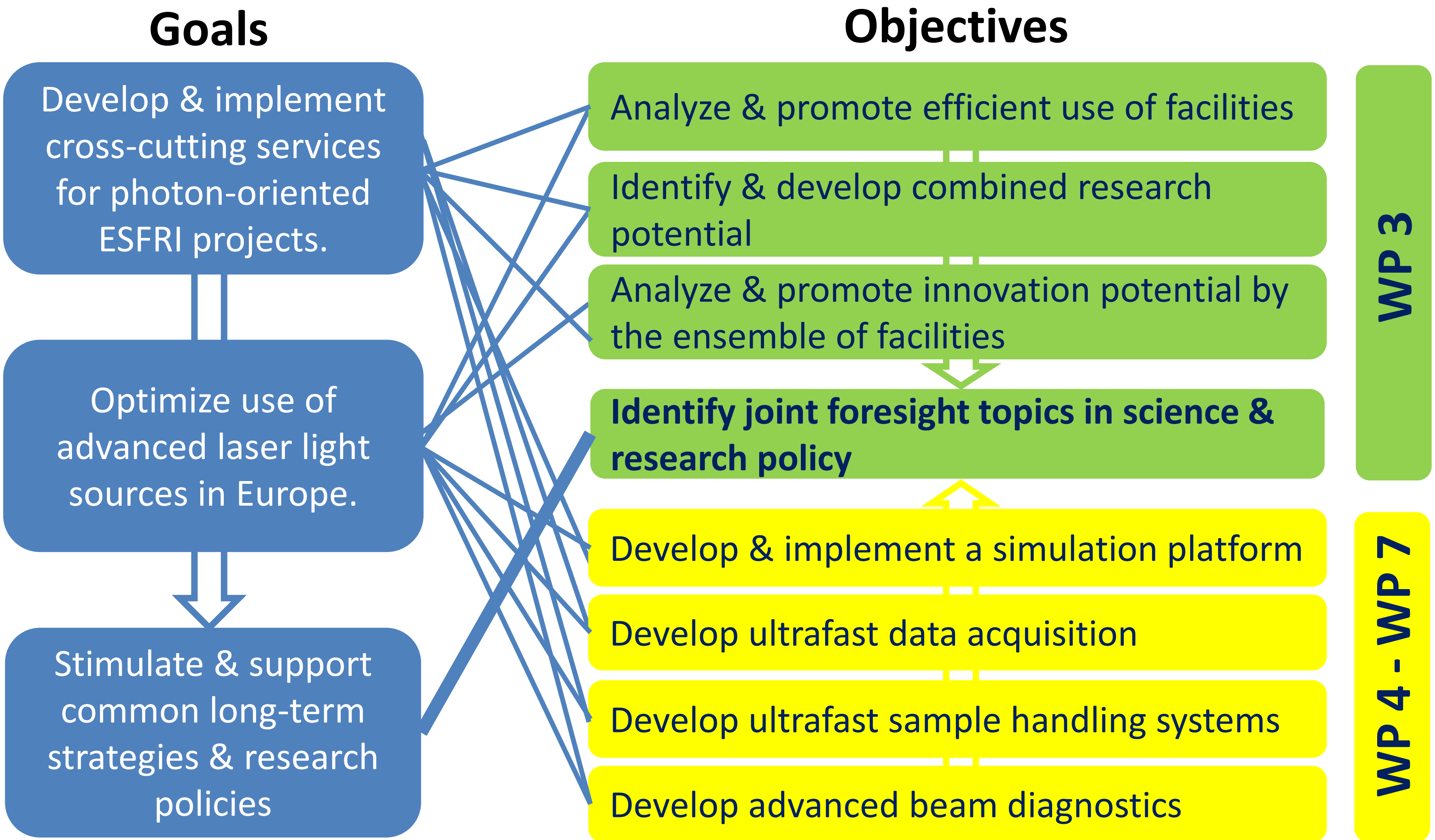
EUCALL's Strategic Goals and Objectives



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WP4 - SIMEX: Simulation of Experiments

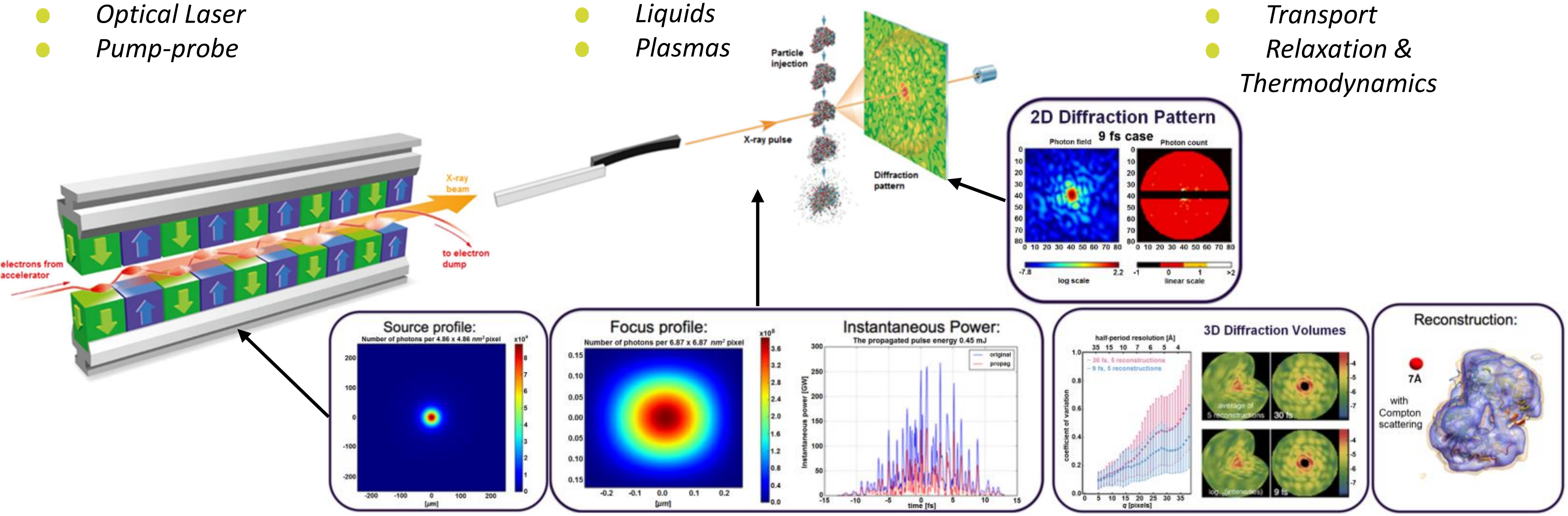
Photon Source
- XFEL
- Synchrotron
- Optical Laser
- Pump-probe

Photon Waveguide
- Lenses
- Mirrors

Target/Sample
- Single particles
- Solids, surfaces
- Liquids
- Plasmas

Detection
- Spectroscopy
- Imaging

Photon Data Analysis
- Structure determination
- Electronic structure
- Transport
- Relaxation & Thermodynamics



https://github.com/eucall-software

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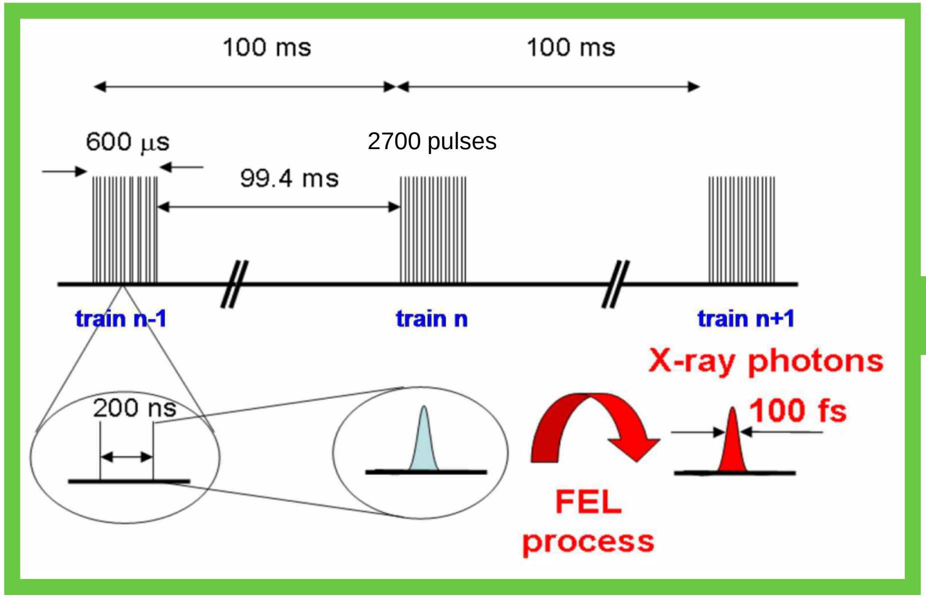
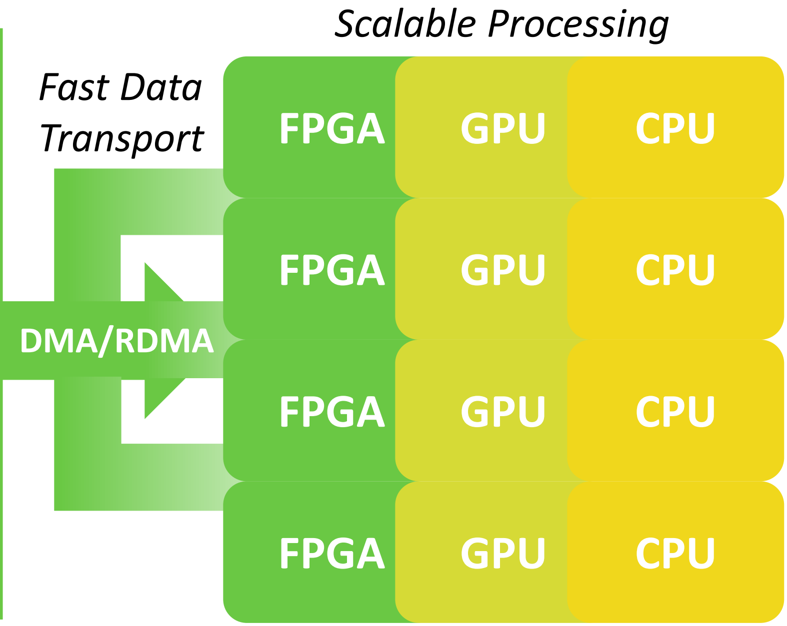
WP5 - UFDAC: Ultrafast Data Acquisition

European XFEL pulse train





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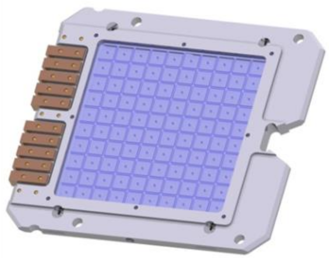
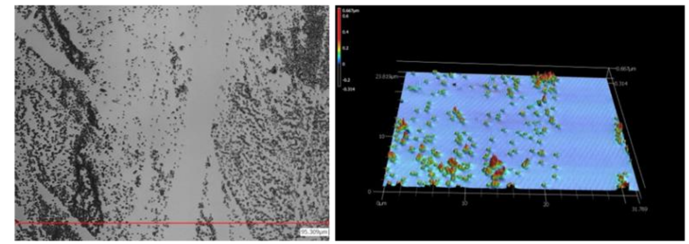
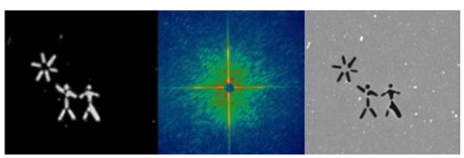
WP6 – HIREP: High Repetition Rate Sample Delivery

Sample Pre-Investigation Workflow





Sample automatically screened via microscope and points of interest identified and logged.




From the generated coordinates, sample is raster scanned at 10 Hz at beamline for analysis.

By Carsten Deiter (XFEL.EU)

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WP6 - HIREP: High Repetition Rate Sample Delivery

A standard sample holder including cooling and heating capacities – to be used by all participating institutes and their users

- integrated with high precision sample stages
- ultrahigh vacuum–compatible fluorescence and reflection **microscope** for sample positioning

Automatic sample identification and localization software

- to control the sample stage
- available for all institutes to be integrated in their instrumentation

Milestones already achieved:

- Specification for sample holder and sample stages (Nov 2015)
- List of sample types for identification software compiled (Jan 2016)
- Specification of the UHV microscope (Mar 2016)

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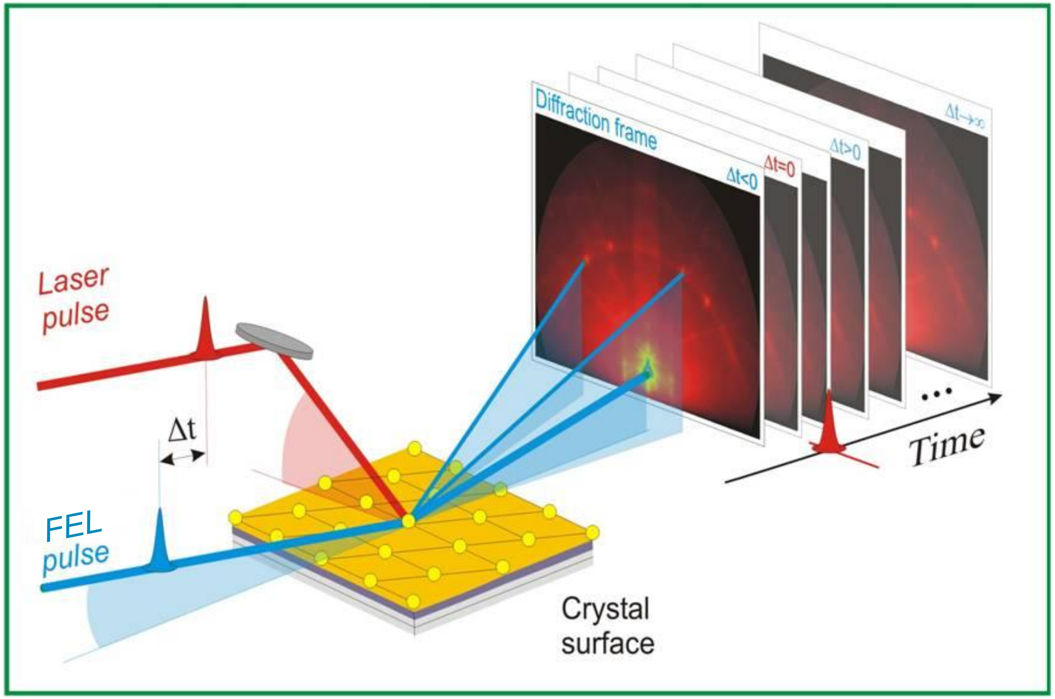
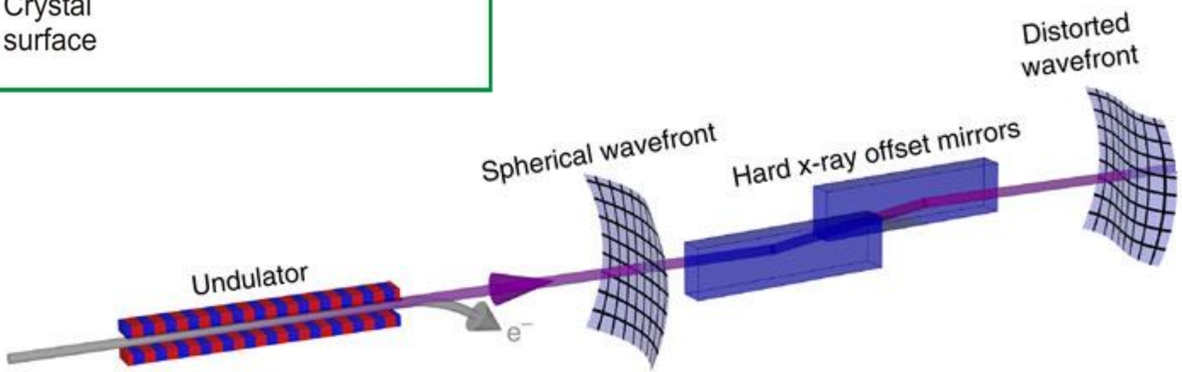
WP7 - PUCCA: Pulse Characterisation and Control



From Gedik Group (MIT)



Rutishauser et al, J Synchrotron Rad **20** (2013)

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EUCALL Work Packages

- WP1 – **Management** of the EUCALL Project
- WP2 – **Dissemination** and Outreach

- WP3 – **Synergy** of Advanced Laser Light Sources

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WP3 – Synergy of Advanced Light Sources

- Analyze & promote efficient use of facilities
- Identify & develop combined research potential
- Analyze & promote innovation potential by ensemble of facilities
  - Collect information from RIs about: science applications, techniques/methods, available instrumentation, operational matters (beamtime allocation and scheduling, procedures)
  - Cross-community activities; experience exchange; joint (user) training
  - Analyze & develop suggestions for future collaboration
- Identify joint foresight topics in science & research policy
  - New science & technology applications using OL and X-ray background and expertise
  - Sustained collaboration
  - (to be identified) …

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EUCALL Young Researcher Travel Bursaries

- EUCALL provided 10 Young Researcher Travel bursaries for the ELI Summer School

INIVITATION TO ELI AND HILASE SUMMER SCHOOL (ELISS 2016)

DOLNÍ BŘEŽANY, THE CZECH REPUBLIC

21.8. 2016 – 26.8. 2016

- EUCALL will provide 23 Young Researcher Travel bursaries for the Science@FELs Conference

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Summary

- EUCALL addresses technological overlap between SR, FEL and OL RIs
- EUCALL develops standardised software and hardware tools for
  - Simulation of Experiments
  - Ultrafast Data Acquisition
  - High Repetition Rate Sample Delivery
  - Pulse Characterisation and Control

- Synergy WP will foster new collaboration between RIs
- Young Researcher Travel Bursaries for Conferences and Summer Schools
- 1st Annual Meeting 31 Aug – 2 Sept 2016

- Collaboration already successful after ten months

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Thank you for your attention

www.eucall.eu / contact@eucall.eu

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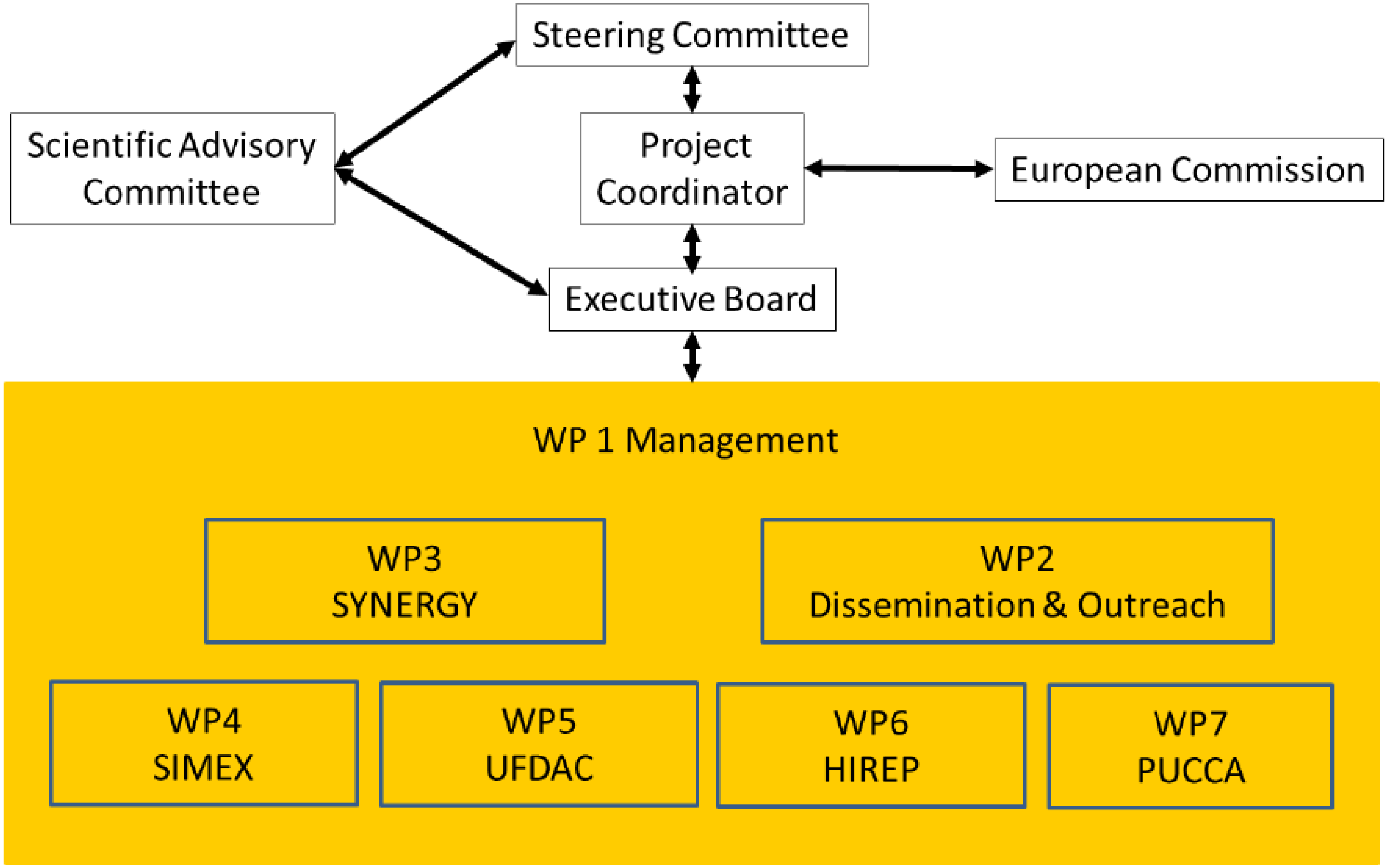
EUCALL Management Structure



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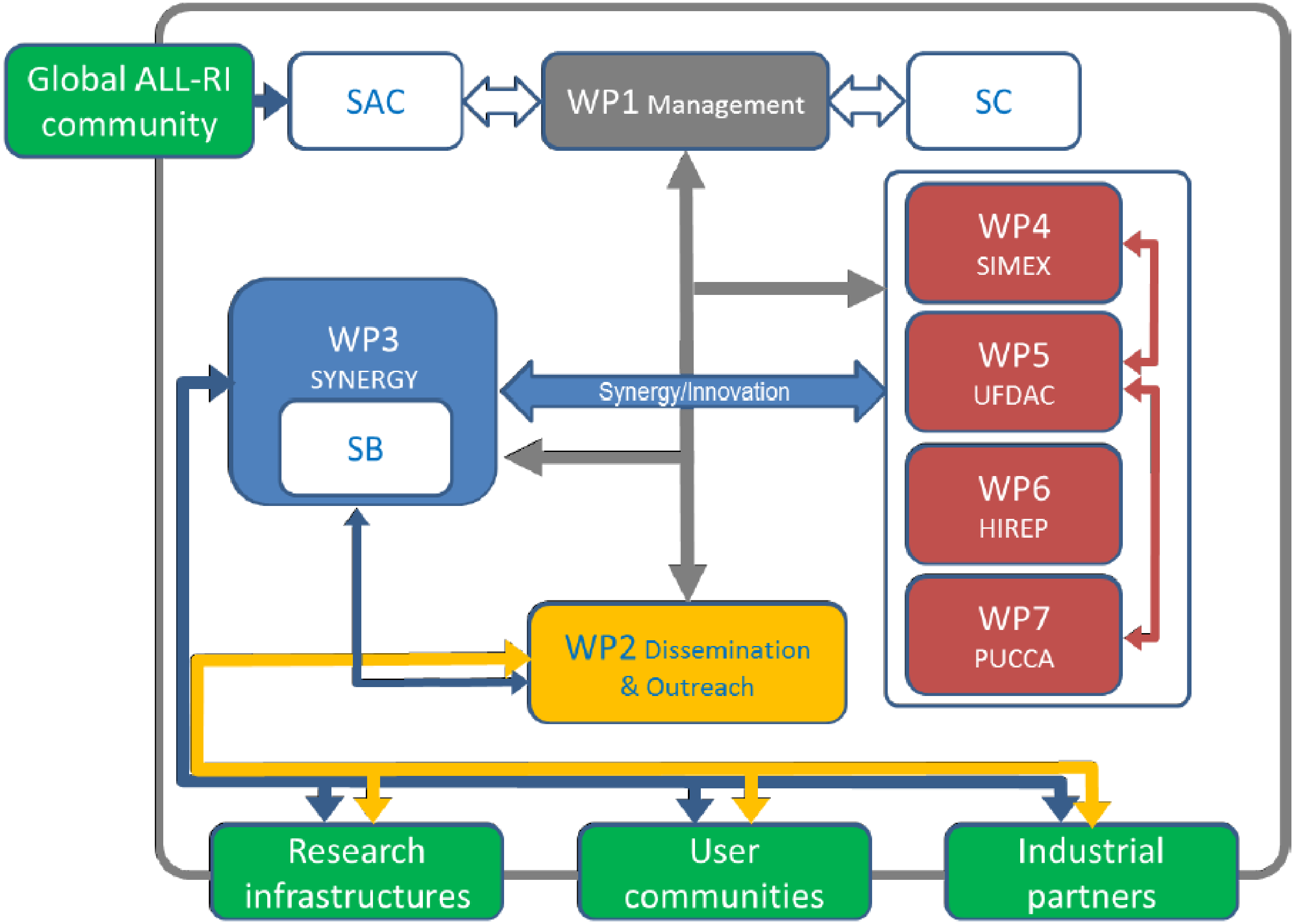
EUCALL Internal and external communication



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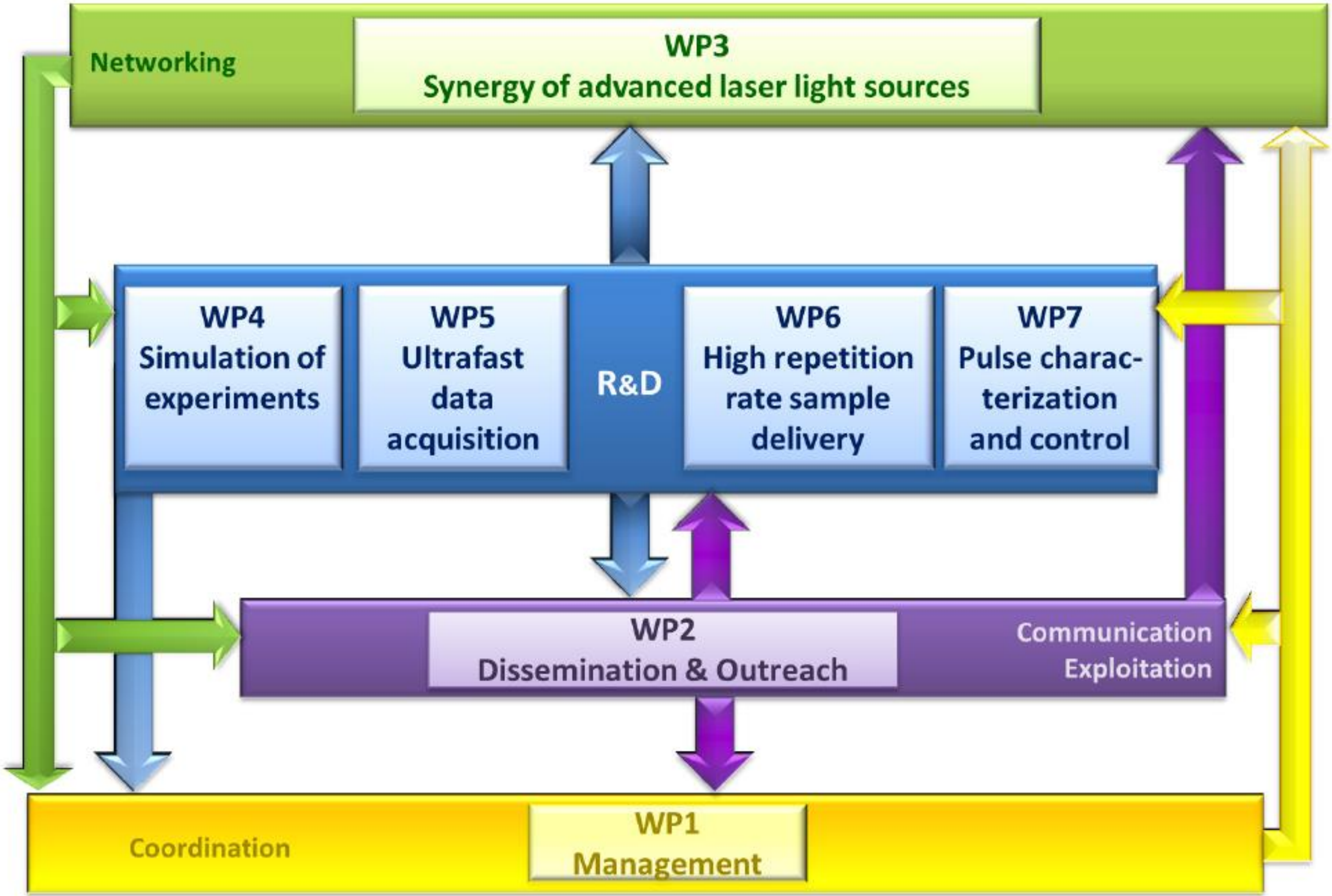
EUCALL Interaction between the WPs



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WP4 - SIMEX: Simulation of Experiments

Develop and implement a simulation platform for experiments at the various RIs.

Organization

- WPL: XFEL.EU (36 PM); WPC: HZDR (36 PM); participants: DESY (36 PM), ELI (36 PM), ESRF (36 PM)

Activities/tasks

- Delivery of individual sim. modules & common interfaces for interoperability
- Simulation from source to signal
- Test and validate modules and workflow, including HPC workflow

Deliverables

- 2 design reports (M12); Interoperability (M24); Simulated data for plasma experiments (M24); Testing, validation & example workflow (M36)

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WP5 - UFDAC: Ultrafast Data Acquisition

Ultrafast online image processing, data transfer and injection, and processing of digitiser data for femtosecond/attosecond photon sources.

Organization

- WPL: HZDR (36 PM); WPC: XFEL.EU (36 PM); participants: DESY (12 PM), ELI (42 PM), ESRF (24 PM), PSI (48 PM)

Activities/tasks

- Online 2D image processing
- High-speed data transfer and data injection
- Online processing of digitizer data

Deliverables

- Report Online 2D image processing (M36); Report High-speed data transfer and data injection (M36); Report Online processing of digitizer data (M36)

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WP5 - UFDAC: Ultrafast Data Acquisition

Tasks

Development of FPGA and GPU programming as part of the DAQ chain for the

- Acquisition and online processing of data
- Quality enhancement
- Data compression
- Treatment techniques (e.g. image and pulse analysis, vetoing, selection, correlation)

This takes place at the front-end detector electronic and optionally connected GPUs before the Computing and Storage clusters.

- Joint development of high-speed data interfaces and injection techniques to allow online processing and transfer to following analysis and storage clusters.

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UFDAC Data Structures and Interfaces

Definition of a set of common working points to address within UFDAC

- All data formats fall into one of the two categories of image data or digitizer data.
- Fast data processing will be done via FPGA- or GPU-based solutions or a mix thereof.
- For this, all applications of all partners are ready to share solutions that are based on C/C++/Python/VHDL.
- For fast data injection, (remote) direct memory access is of great interest.
- Yet, the scalability of the DAQ chain has to be addressed as it is necessary for future data rates to maximize both bandwidth and scalability.
- A starting point for scalable solutions will be data injection and subsequent analysis based on standard network hardware and protocols rather than application-specific hardware and protocols. Solutions favoring TCP/IP, UDP and Infiniband can be shared among the partners
- Yet, PCIe and MicroTCA will be considered when developing solutions for (remote) direct memory access
- (Parallel) HDF5 is the de-facto standard for file input/output used among all partners and can form the basis for defining common meta data formats that describe a minimum set of common scientific data and DAQ data for use by common software solutions.

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WP6 - HIREP: High Repetition Rate Sample Delivery

Integrated concept for decentralised sample characterisation and fast sample positioning for all RIs

Organization

- WPL: ELI (24 PM); WPC: XFEL.EU (24 PM); participants: DESY (24 PM), HZDR (12 PM), LU (24 PM)

Activities/tasks

- Automatic sample screening
- Position control

Deliverables

- Design report (M13); Prototype (M18); Beta version sample identification software (M18); Report on EMP compatibility (M24); Prototype (M30); Prototype (M30); Release sample identification software (M36); Final integration (M36)

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HIREP Sample Holder / Stage 1

Periodically placed or manufactured targets on a support / substrate of equal or similar shape

- foils placed in a sandwiched holder with holes / windows
- flat cones of 10s of µm tip and 100s of µm base (lithography)
- micro dots with a size from 1 µm - 100 µm
- reduced mass and nanostructured targets
- µm sized biological samples positioned by pick-and-place
- wires spanned across µm sized holes / windows

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HIREP Sample Holder / Stage 2

Statistically distributed targets on a support / substrate

- dried out suspension with sphere shaped single particles or clusters of them
- self-organized growth of metallic / semiconductor / insulator micro structures
- solid foams of two chemical components with open surface / pores
- crossing points inside of ravels of filament like materials (nano / micro wires / fibers)

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HIREP Sample Holder / Stage 3

Homogenous materials with defects / cracks / discontinuities

- metallic glasses like GeO_2, SiO_2(80%)+Na_2O_2(20%)
- thin films of metal / semiconductor / insulator materials on metal / semiconductor / insulator substrates
- thin films of metal / semiconductor / insulator materials structured with metal / semiconductor / insulator nano and micro structures

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HIREP UHV Microscope

- The microscope should be vacuum compatible and allow use in an UHV environment (pressure: < 10^{-6} mbar).
- The microscope should be mounted on a CF-flange for easy exchange. The design should be as compact as possible.
- For fine positioning the microscope can be positioned as a single unit (optics and CCD camera) with an accuracy of better than 1 μm and a travel range of > 2 mm in x,y,z direction.
- The CCD camera should be placed outside vacuum at atmospheric pressure, the microscope objective will be placed in vacuum.
- Separation between vacuum and atmospheric pressure will be achieved by placing a vacuum window in the infinitely corrected optical beam path.
- The microscope should be based on on-axis viewing in order to avoid parallax errors.

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HIREP UHV Microscope 2

- As an option it should be possible to exchange the microscope objective if required.
- The field of view should be more than 0.3 x 0.3 mm.
- An optical resolution of better than 1 μm is required aiming at sub-micrometer positioning accuracy.
- The depth of field should be limited to less than 10 μm as this will be used for alignment of the target in the beam direction.
- For fluorescence microscopy the design should allow to place different filters into the beam path. The system should be compatible with different illumination sources.

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WP7 - PUCCA: Pulse Characterisation and Control

Pulse arrival time monitors with fs time resolution, wavefront sensor and analysis software, and a transparent intensity monitor

Organization

- WPL : DESY (36 PM); WPC: XFEL (36 PM); participants: ELETTRA (24 PM), ELI (12 PM), ESRF (24 PM), HZDR (36 PM), PSI (0 PM)

Activities/tasks

- Delivery of arrival time monitors between two independent pulsed light sources with femtosecond time resolution
- Development of a wavefront sensor and analysis software
- Precise transparent intensity monitor

Deliverables

- Report (M12); Report (M15); Report (M18); Prototype (M30); Prototype (M36); Prototype (M36); Report (M36); Software manual (M36); Report (M36)

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WP7 - PUCCA: Arrival Time Monitors

Task 7.1 - Delivery of arrival time monitors between two independent pulsed light sources with femtosecond time resolution

Task 7.1.1 Accelerator-based arrival time monitor:

Use of intense THz radiation generated e.g. at the exit of the last undulator to drive an electro-optic sampler, which is transmitted by an extremely chirped white light pulse from the second laser source (HZDR, PSI).

Task 7.1.2 Liquid-jet based arrival time monitor: (Nearly) co-propagate both light pulses (one remaining ultrashort, the other chirped-stretched to a few picoseconds) through a liquid flat sheet jet, doped with selected chromophores which react efficiently to the wavelength of the ultrashort light pulse (XFEL, ELI).

Task 7.1.3 Combine both tools at one EUCALL RI to correlate and deselect pulses at the second device, when they are outside its timing window (HZDR, XFEL, ELI, PSI)

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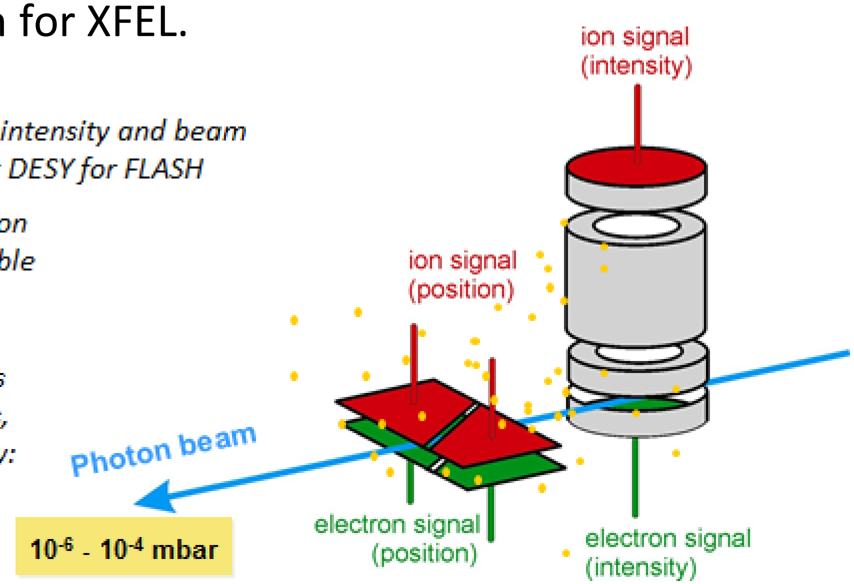
WP7 - PUCCA: X-ray Intensity Gas Monitor

Task 7.3.1 Analysis of X-ray intensity monitors based on gas ionisation (DESY): study of the ultimate uncertainty achievable with transparent XGM for EUCALL RIs, design study of optimized XGM design for XFEL.

Gas-monitor detectors for online intensity and beam position monitoring developed at DESY for FLASH

- *Based on atomic photoionization → no degradation, indestructible*
- *Low particle density → transparent*
- *From time of flight of electrons photoionised from noble gases, uncertainty of the pulse energy: less than 10%*



Task 7.3.2 Construction and test of a prototype X-ray intensity monitor (DESY). Optimised for intensity measurements of hard X-rays with ultimate precision, test at XFEL or LCLS; at ELI sources and other FELs as much as possible.

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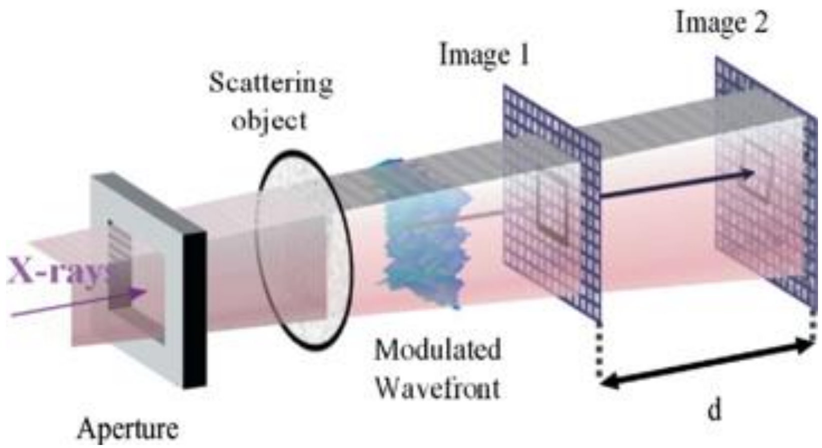
WP7 - PUCCA: Wavefront Sensor + Software

Task 7.2 Development of a wavefront sensor and analysis software



Use the speckle as markers and track the trajectory of the X-rays

S. Berujon, ESRF

DLSR 2016 Workshop, DESY

- Prototype speckle tracking wavefront sensor developed for ESRF
- For transferability to XFEL a non-invasive device is needed.
  - Non-invasive wavefront sensor upstream from the sample based on two semi-transparent screens
  - An invasive wavefront sensor behind the sample
- Sensor for x-ray repetition rate higher than 40 Hz will be examined

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