Work Package 2: Real-time Data Processing

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Real-time Data Processing – Concepts in POF2

1. DAQ hardware
   - Pixel Detectors
   - Essential Data Reduction

2. PC-based processing
   - Data Reduction
   - Data Processing
   - Online Assessment Visualization

Technologies
- Programmable hardware
  - FPGA, DSP, embedded GPUs
- „Parallel Computing“:
  - PC + Coprocessing / GPU

Tasks
- Selected commercial hardware
- Standardized custom hardware
- Hardware independent programming (e.g. OpenCL)
- Library of common algorithms

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Real-time Data Processing – Milestones in POF2

• Data processing with dedicated hardware
  – programmable hardware platform

• Real-time data assessment with parallel computing:
  – Development of computation system based on GPU co-processors
  – Prototype adoption of a complete PX data flow
  – Implementation of an online tomographic reconstruction

• General environment for parallel image processing
  a) Independent from available hardware (OpenCL)
  b) Library of standard algorithms
  c) Easy adaption to new problems
MTCA.4 (MTCA for Physics)

- RTMs for large channel numbers
- HGF AMC = Multipurpose readout board for several XFEL Machine controls
  - FPGA-based
  - High speed serial links (10G Ethernet)
- Last workshop in Karlsruhe, Dec 14
  - DESY, GSI, FZJ, HZDR, KIT
  - Development of common HGF-AMC Board support package
- Also part of Detector Program (DTS)
**Smart scientific cameras**

- **Detectors for high speed imaging**
  - What is commercially available?

  - Scientific sensor developments?
    - **CMOS sensor**

  - **pco.dimax 4MP@1300fps**
    - (7500MB/s)

  - **Internal Memory**
    - e.g.: 36GB → 5s

- **Readout**
  - Camera Link (250 / 850 MB/s)
  - USB3 (new: 500 MB/s)
  - GigE Vision (125 MB/s)

- **Data rates limit camera performance**

- **No online data analysis**

- **Custom embedded logic is missing**
Goal:
- Rapid development of DAQ systems for high-speed sensors

1- Pluggable sensor interface
2- Modular FPGA architecture
3- High-speed links
4- Parallel Computing

Goal:
- Rapid development of DAQ systems for high-speed sensors
- Average data throughput of 3.5 GB/s (DMA max data transfer @ 4 GB/s)
- No bit errors observed (tested up to several TB of data exchanged)

Memory Write Performance (Average)

- GEN 1
- GEN 2

Dash lines theoretical limit

Support for PCIe Gen 3 is in progress

L. Rota et al. IEEE Real Time Conference 2014
FPGA: Virtex 6 -> XC6VLX240–2 FF1759

Same logic functions

PCLIe-DMA Engine – Floor map

Commercial DMA

NW DMA engines

PCIe and GTX HW-core

DMA engine
Application 1: Smart phase contrast camera

- Goals:
  - Automatic grating control
  - Online reconstruction (with GPU)
Application 2: Picosecond Pulse Sampling

1. **Sampling**: each pulse sampled with 4 samples by KAPTURE system, minimum sampling time of 3 ps.

2. **Data transfer**: digital samples transferred to high-end GPU (Graphics Processing Units) by a PCIe-DMA architecture.

3. **Real-time GPU data elaboration**: pulses reconstruct, amplitude and peaking time respectively with “mV” “picosecond” accuracy are evaluated.
KAPTURE System

- Pulse input
- LNA
- Wideband power divider
- DC-DC power supply
- KAPTURE board
- High throughput readout board
- PCIe link
CSR fluctuation in time domain with YBCO detector

CSR frequency behaviour vs. different bunch current

ANKA
184 bunches
revolution time 368 ns

Train 1 and 2
2 ns
Possible filling scheme at ANKA

Acquired with Schottky diode

KAPTURE Measurements

Possible filling scheme at ANKA

Peak pulse amplitude

Turn

Sampled bucket

CSR frequency behaviour vs. different bunch current

Acquired with Schottky diode

Burst threshold

峰脉冲幅度
General environment for parallel image processing

How to support code development for GPUs?

Requirements:
- Processes data streams (usually 1 to 4 dimensional floating point data)
- Detect and use all hardware resources

Developer:
- Hides parallelization and concurrency details
- Management of memory transfers
- Multiple implementations (e.g. for CPU + GPU)
- Automatic scheduling

User:
- Simple end-user interface
  - GUI + Scripting
- Modular algorithm design
UFO Parallel Processing Framework

- Free and open-source
- Supports OpenCL parallel hardware
- Hardware-specific optimizations
- Fast pipelined architecture
- Scheduling across multiple devices and nodes
- Introspection interface to Python and other scripting languages
- Integrated with Tango control system

Reconstruction w single GPU (GB/s)

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Used at:
- ANKA
- ESRF
- PETRA 3
- HZDR

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POF3 proposal

“Common to all large-scale facilities is […] how to cope with the huge amounts of data […] in terms of real-time analysis, evaluation, storage and archiving. To meet this challenges […] MML continues […] HDRI […]”

New work package structure

1. Standard Data Format and Offline Data Processing Frameworks
2. Fast Online Data Processing Frameworks
   - Scalable Parallel Computing
   - Configurable Data Acquisition Systems
   - Online Data Processing Frameworks
3. Scientific Computing

Review: Strengthening of this initiative is of fundamental importance
WP2: Fast Online Data Processing Frameworks

Milestones:

• Standard platforms for online monitoring
  – High-performance acquisition and computing hardware
  – Fast control system for computationally intensive applications

• Applications based on DAQ hardware and computing platforms

• Near-time analysis frameworks
  – Early data quality checks
  – Based on DPDAK, DAWN and UFO-Framework

• Application of real-time data processing + data quality checks

• Web portals for data access and remote computing
  – Integration of online tools
## Resources

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<th>Helmholtz Centre</th>
<th>POF (FTE)</th>
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Source: POF3, Volume 3
HDRI in the Research Programme “Matter”

- Matter and Universe
- From Matter to Materials and Life
- Matter and Technology
- Detector Technology and Systems (DTS)
- Data Life Cycle Lab (DLCL)
- Large-scale Data Management (LSDMA)

Data Management for Large Infrastructures
- High Data Rate Processing and Analysis Initiative (HDRI)
- European Initiatives
  - Pandaas
  - CDMA
  - NIAC
- National Funding
  - “Verbundforschung”
  - German-Russian Funds
Detector Technology and Systems (DTS)

Sensors, ASICs and Interconnects

Data Transmission and Processing

Detector Systems

- HGF-Cube
- Compact Gaseous Detectors
- Fast Photon and X-ray Detectors
- Fast Timing Detector Systems
- CMOS Sensor Systems

Networking, Outreach and Applications beyond “Matter”
DTS Activities

Selected Milestones:
• Common technology platform based on Helmholtz AMC
• Scalability of CPU/GPU clusters for DAQ systems
• Helmholtz-Cube / Lambda
• Multi-channel bolometric detector systems

Highlighted projects (Common fund):
• Ultrafast 1D line detector for optical and near IR radiation
  – Caselle, Hiller, Müller, Rota, Weber (KIT), Correa, Dariusz, Gerth, Graafsma, Steffen (DESY)
• New DAQ-Electronics demonstrator system for X-Ray tomography
  – Kaever (HZDR), Zimmer (DESY), Balzer (KIT)
Arthropod Structure revealed by ultra-fast Tomography and Online Reconstruction

A new method for ultra-fast X-ray tomography

Science-driven development of

- Management of large datasets
- Cloud-based analysis environment
- Advanced segmentation of 4D X-ray images

Network for functional morphology and systematics:
Cloud technologies enable remote analysis without data download.

**Tasks:**
1. Science-driven
2. Analysis infrastructure
3. Work flow
4. Web portal
5. 4D analysis (e.g. segmentation)

- Access via DFN + DSL
- Remote 3D applications

**ASTOR:**
- Interactive 4D visualization
- ASTOR processing cache
- Managing large-scale datasets
- Long-term archive

**ANKA imaging beamline**

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• **HDRI in POF2**
  - Established technology platform of beamline scientists, engineers, computer scientists, IT departments, …
  - Introduced parallel computing (w GPUs)
  - Common hardware platforms are existing

• **HDRI in POF3**
  - Technologies (cont.)
  - New focus: Data access + analysis of “big data”
  - Resume:
    - “The task are not getting smaller”
    - More resources required
    - Search collaboration with DTS, LSDMA, Universities, …
    - HDRI should be link between beamline scientists and technology experts