A High Throughput Platform for Real-Time X-ray Imaging

Agenda

Synchrotron Tomography at KIT
Platform for Real-Time Monitoring
Parallel FB

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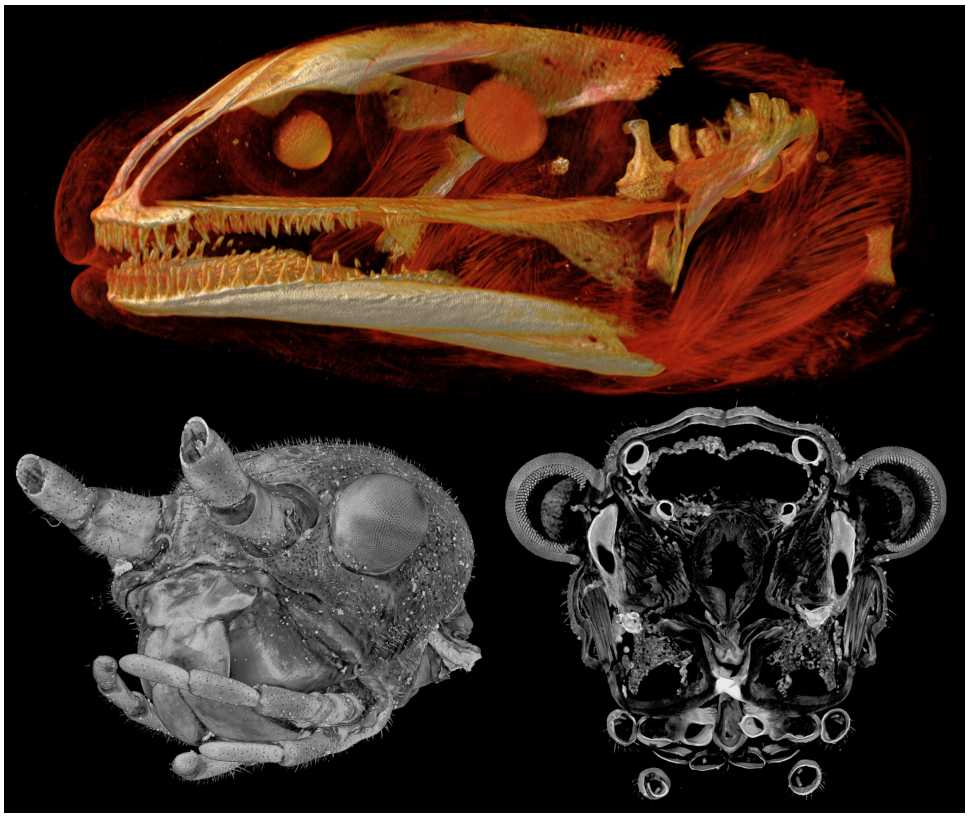
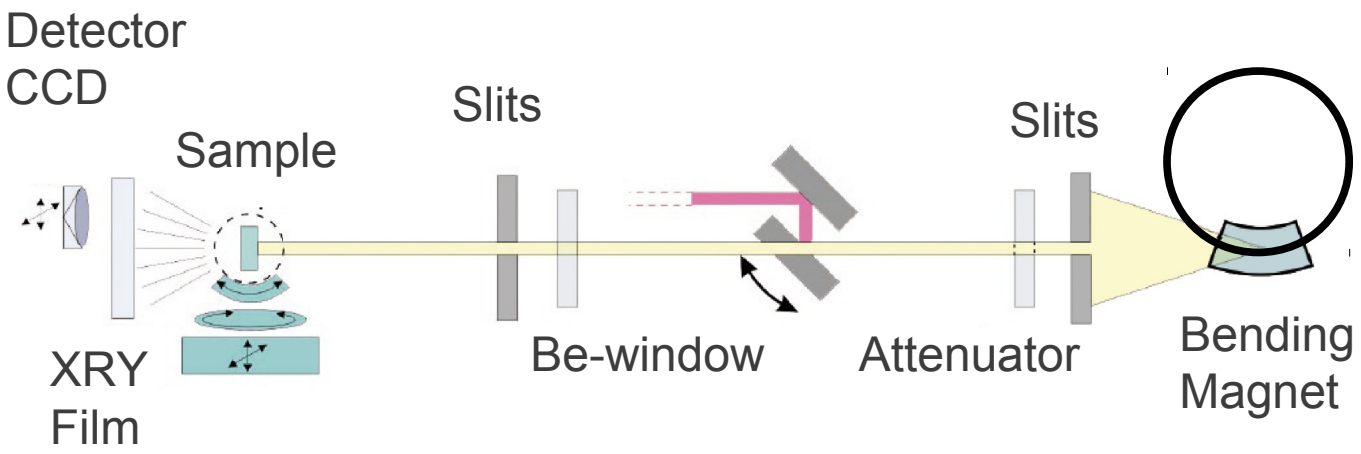


Heads of a newt larva showing bone formation and muscle insertions (top) and a stick insect (bottom), acquisition time 2s.

Tomography Beamline at ANKA Synchrotron

Experiment | DMM Monochromator | Storage Ring



The rotating sample in front of a pixel detector is penetrated by X-rays produced in the synchrotron. Absorption at different angles is registered by camera and 3D map of sample denisity is reconstructed.

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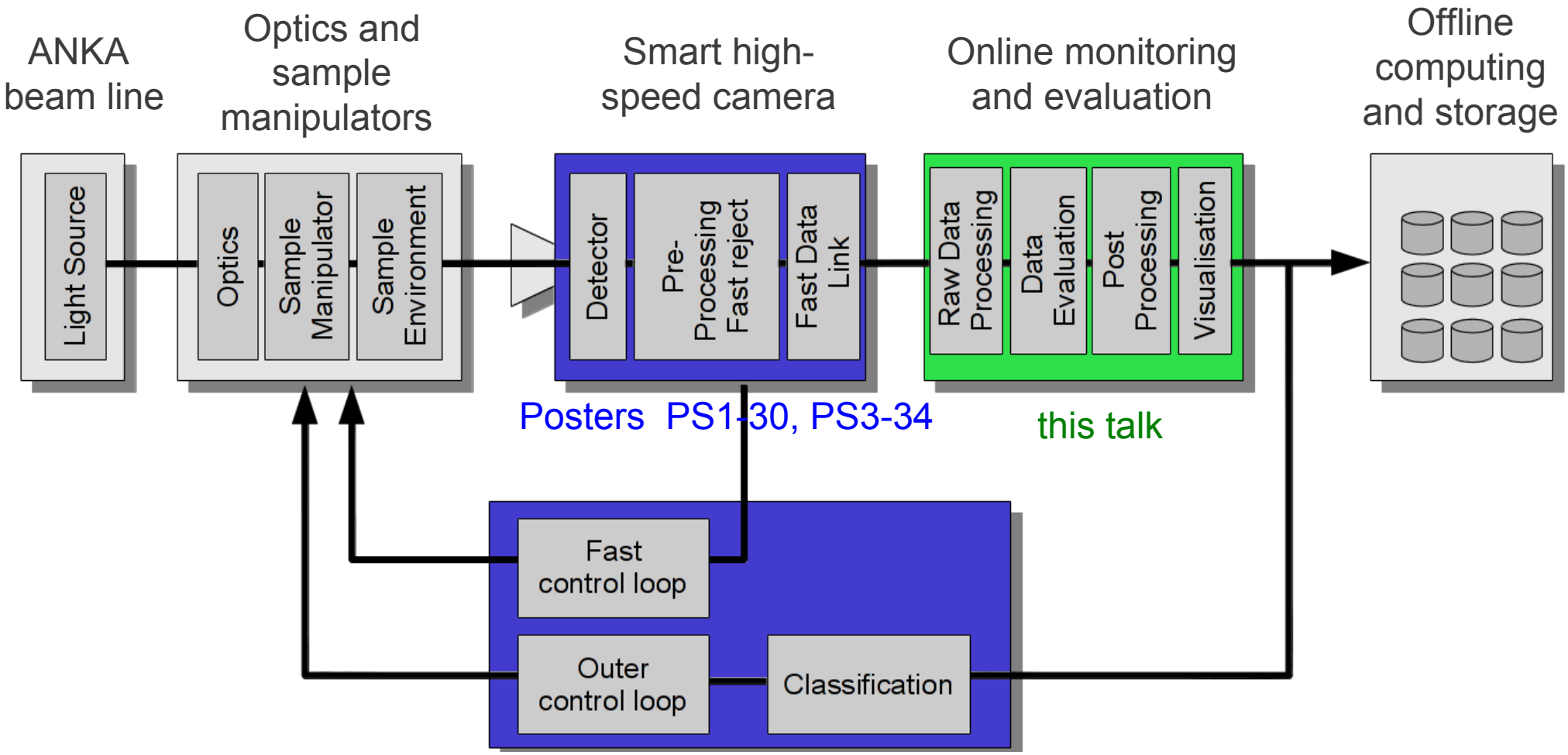
UFO Project

Ultra Fast X-ray Imaging of Scientific Processes with On-Line Assessment and Data-Driven Process Control

Goals

- Increase sample throughput
- High speed tomography
- Tomography of temporal processes
- Allow interactive quality assessment
- Enable data driven control
  - Auto-tunning optical system
  - Tracking dynamic processes
  - Finding area of interest

UFO Schematics



Take a look on our other contributions: PS1-30, PS3-34

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Hardware Platform for Online Monitoring

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Camera

PCO.edge
PCO.dimax
PCO.4000

CameraLink

850MB/s

Ethernet

10 Gb/s

Storage

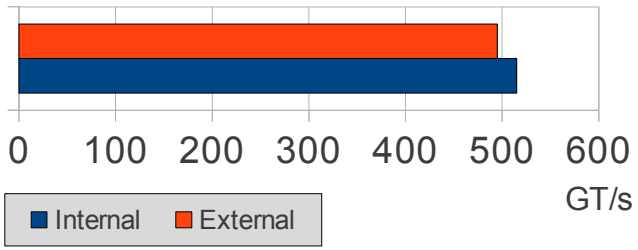
LSDF
Large Scale Data Facility

External PCIe x16 (8 GB/s)

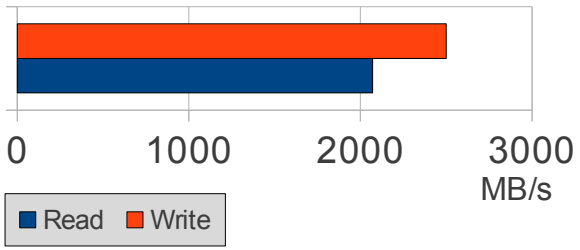
SFF8088 (2.4 GB/s)

SuperMicro 7046GT-TRF (Dual Intel 5520 Chipset)
CPU: 2 x Xeon X5650 (total 12 cores at 2.66 Ghz)
GPUs: 4 x GTX590 External
Memory: 96 GB / 12 DDR3 slots (192GB max)
Network: Intel 82598EB (10 Gb/s)
Camera Link Frame Grabber (850 MB/s)
Storage: Areca ARC-1880-ix-12 SAS Raid
16 x Hitachi A7K200 (Raid6)
8 x Intel SSD 510 (Raid0)

External GPU Box



SSD Raid



SAS Attached Storage

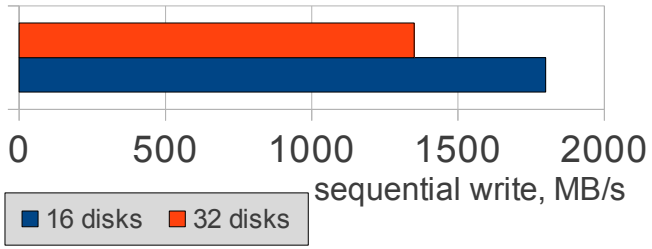


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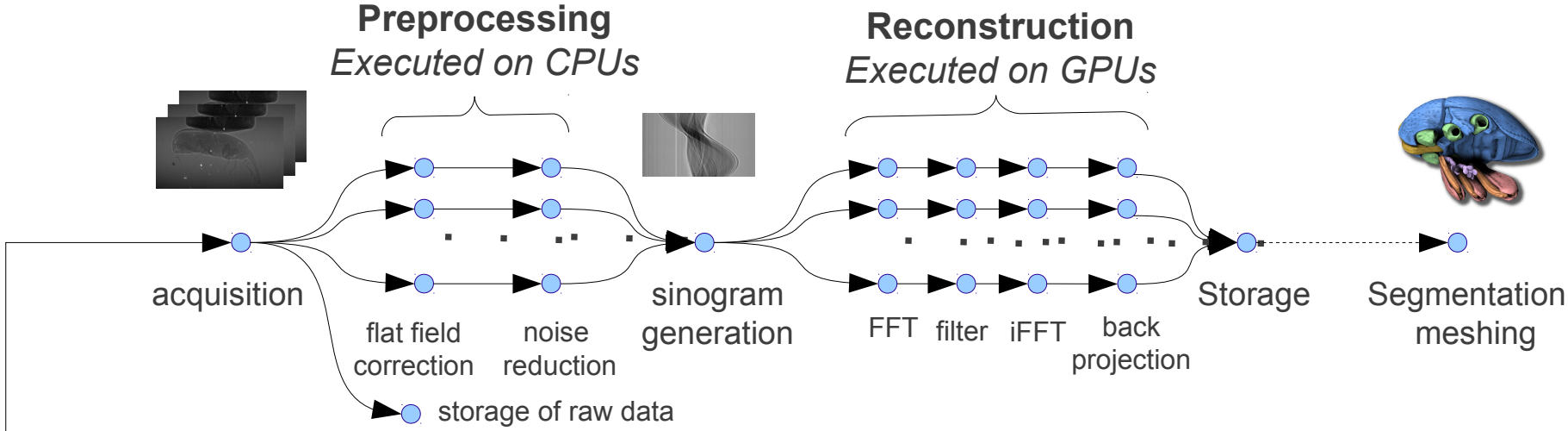
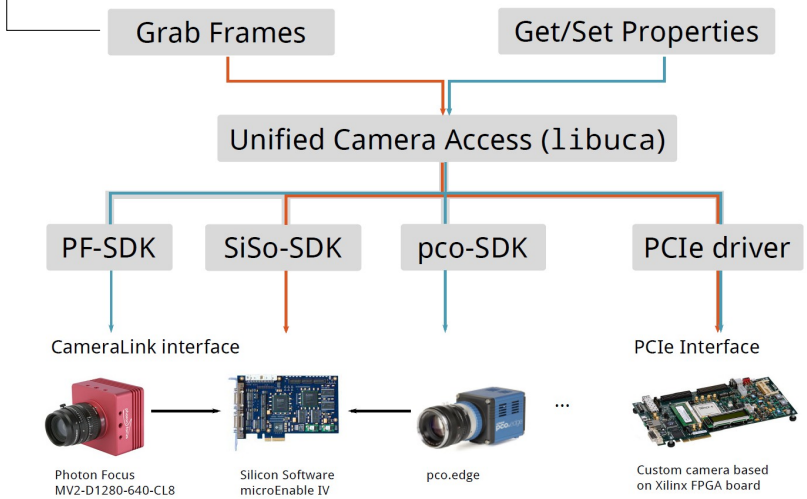
Image Processing Framework





OpenSource
http://ufo.kit.edu/framework

Features

- Easy Algorithm Exchange
- Camera Abstraction
- Pipelined Processing
- Glib/GObject, scripting language support with introspection
- OpenCL + automated management of OpenCL buffers

Filters

Tomography & Laminography
FBP, DFI, Algebraic Methods
Non Local Means for Noise Reduction
Optical Flow

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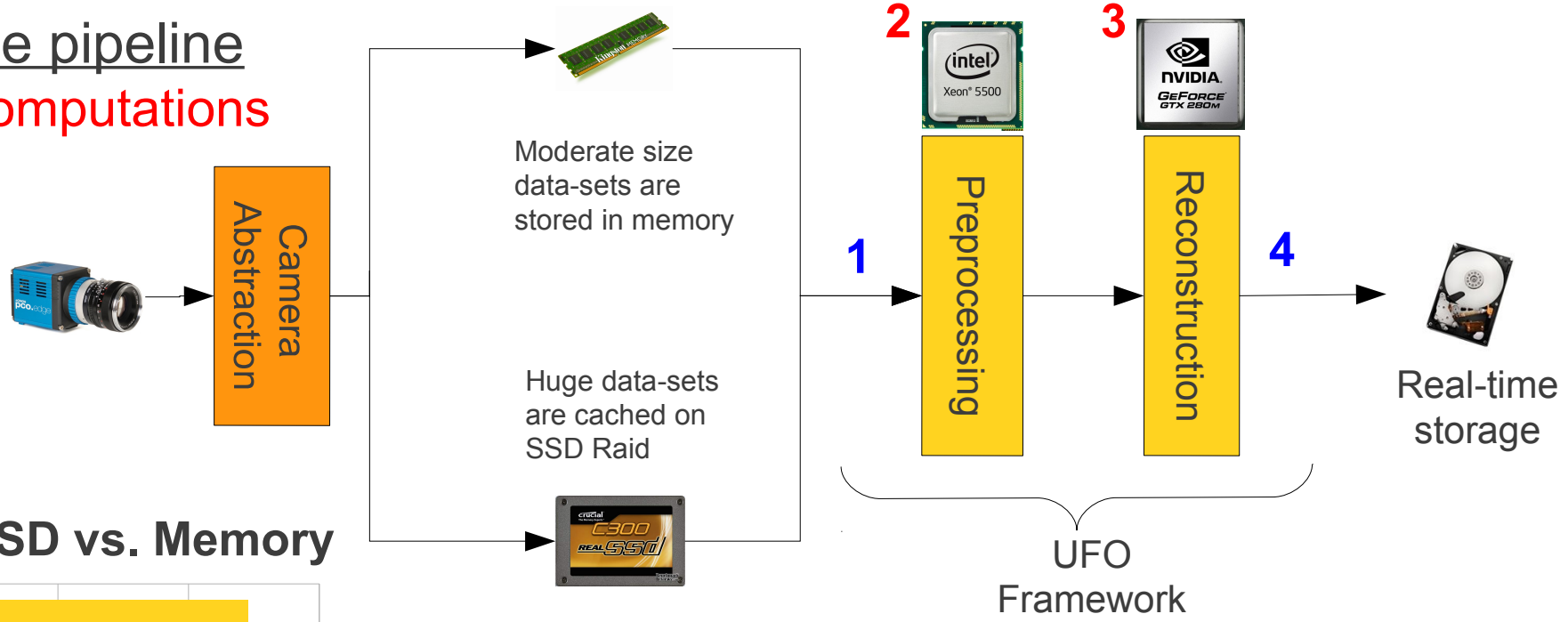
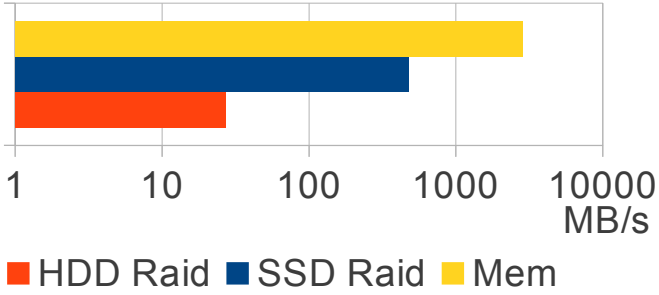
Processing Pipeline

4 stage pipeline

I/O + Computations



HDD vs. SSD vs. Memory



1. Reading data from fast SSD Raid-0 (random reads are effective)
2. Scheduling and preprocessing using SIMD instructions of x86 CPUs
3. Reconstructing on GPUs
4. Storing to Raid on magnetic disks (sequential writes are effective)

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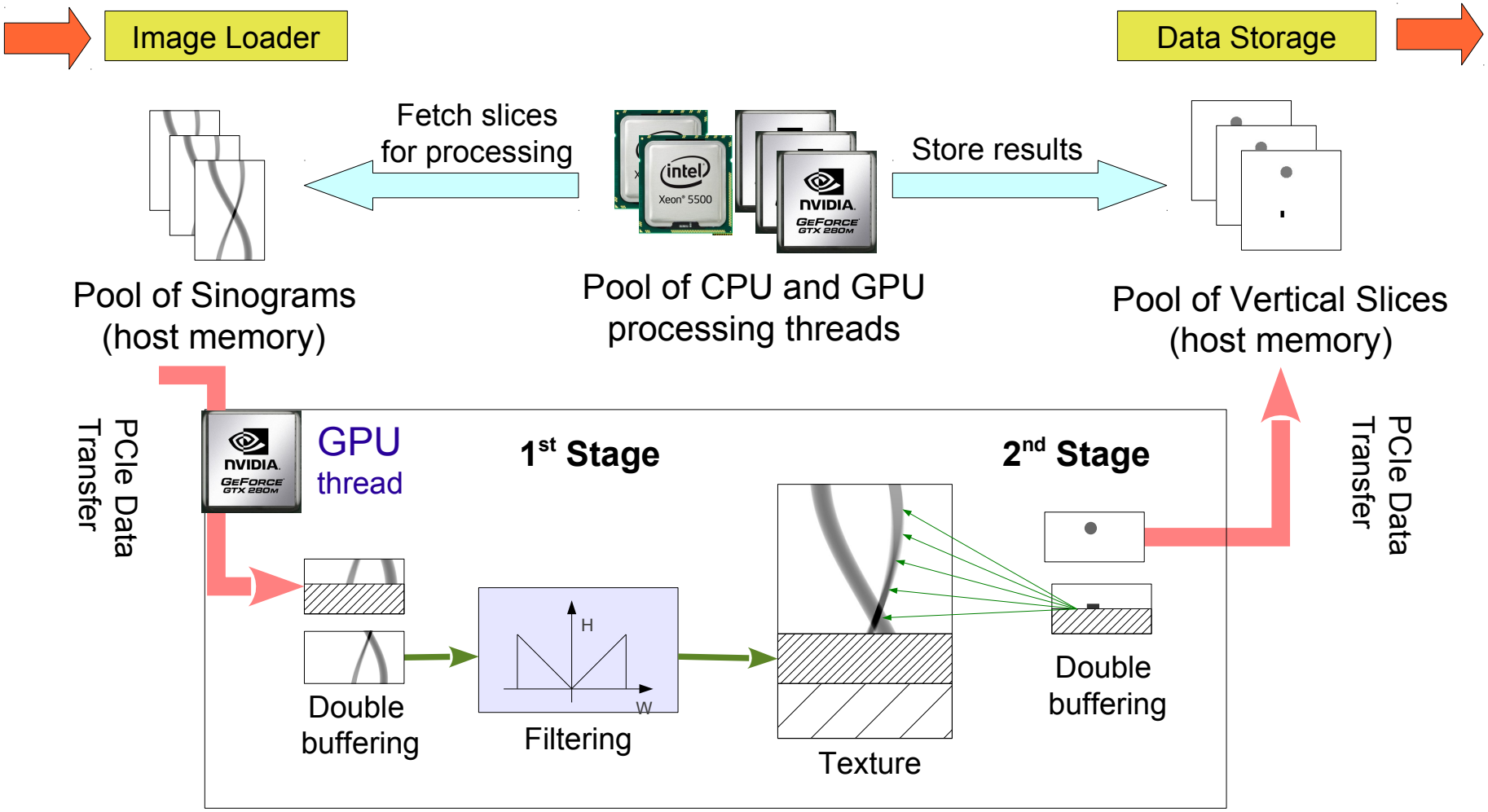
High Speed Tomography on GPU



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Tuning for GPU architectures

Ask for details after session

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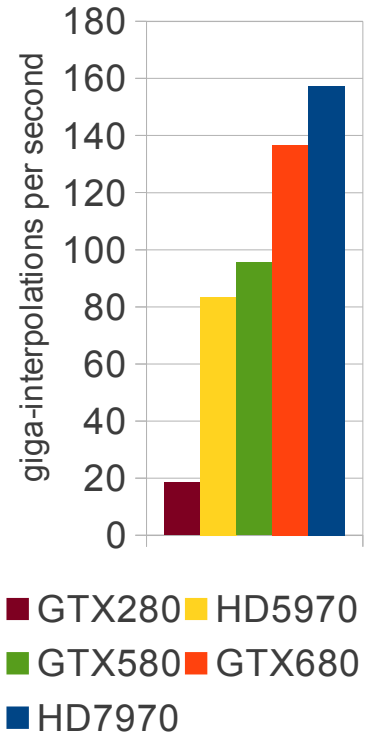
GT200

Base version
Uses texture engine



Fermi +100%

High computation power, but low speed of texture unit
Reduce load on texture engine: use shared memory to cache the fetched data and, then, perform linear interpolation using computation units.

Kepler +75%

Low bandwidth of integer instructions, but high register count
Uses texture engine, but processes 16 projections at once and 16 points per thread to enhance cache hit rate

VLIW +530%

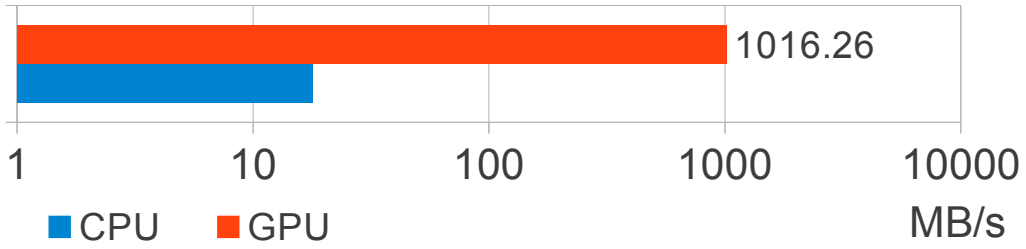
Executes 5 independent operations per thread
Computes 16 points per thread in order to provide sufficient flow of independent instructions to VLIW engine

GCN +95%

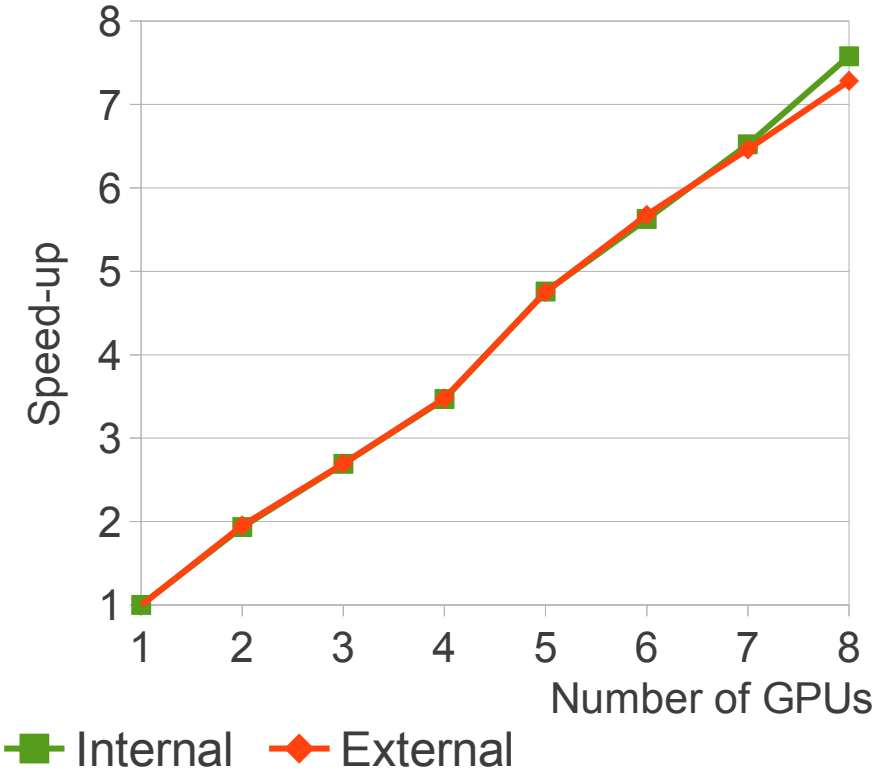
High performance of texture engine and computation nodes
Balance usage of texture engine and computation nodes to get highest performance

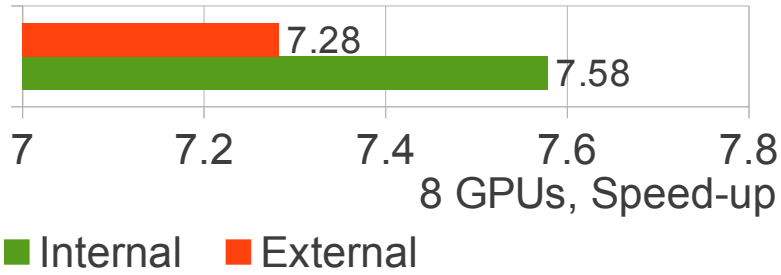
Performance and Scalability

Performance

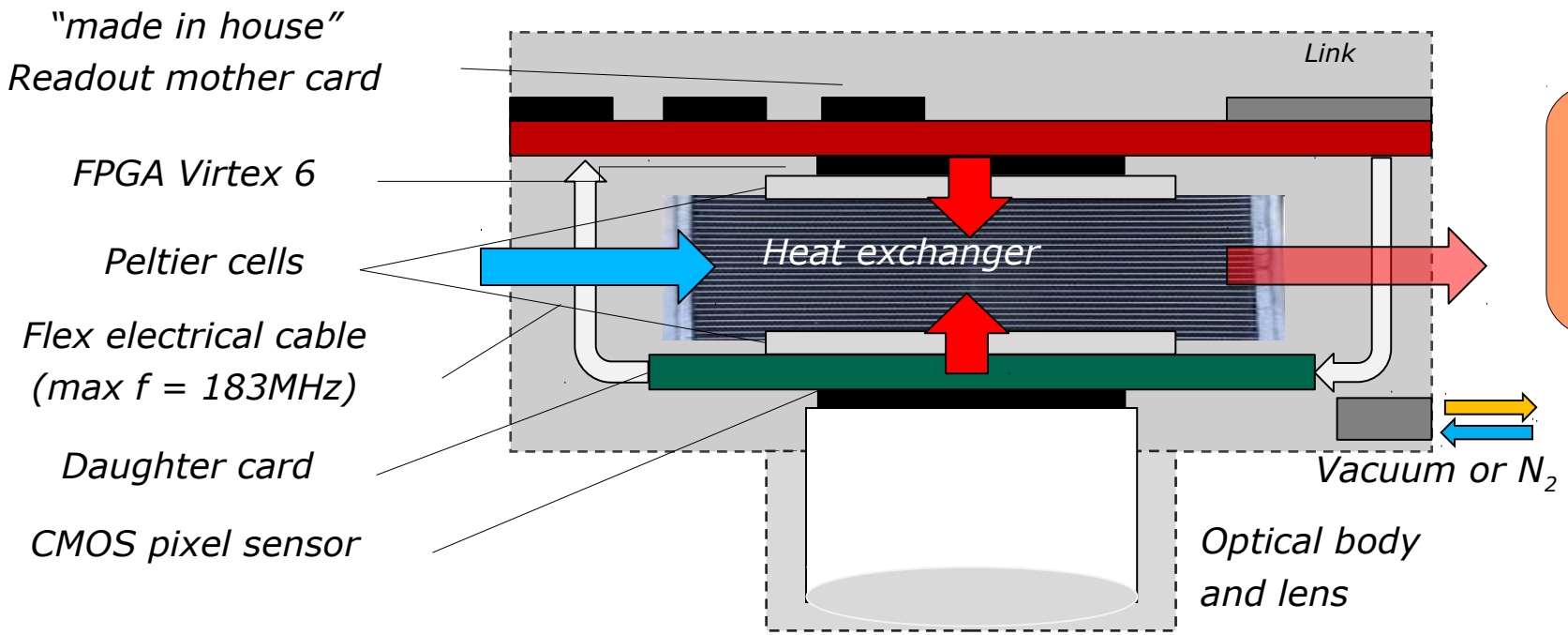


Scalability



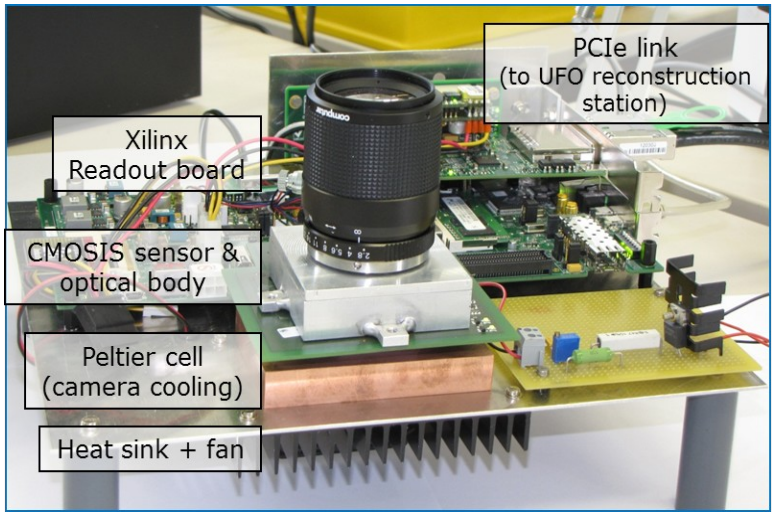


New High Speed Programmable Camera



PS1-30

- ***High speed CMOS sensor***
- ***1Mpix, 5000 fps, 10 bits***
- ***Self-trigger & Data compression***
- ***On-line elaborations and control***
- ***Full Programmability***
- ***Direct connection to Infiniband-cluster***



First Prototype

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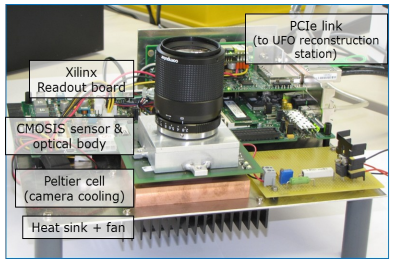
Scaling up to Cluster



Transfer rates up to 10GB/s | 4GB/s | <2 GB/s | 0,25 GB/s

Outer control loop

Real-time control loop

Image sensor

FPGA

Camera
Programmable

Cache

Infiniband
(Optical)

Camera Frontend
Task Scheduler
(CUDA + GPUDirect)

Distributed Storage

OpenCL Node

OpenCL Node

IB router

Storage Node

Storage Node

LSDF
Large Scale Data Facility

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Summary

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- GPU computing fits extremely well the needs of Synchrotron Imaging. However, special care required to get to really high speeds
  - The careful planning is required to avoid I/O bottlenecks
  - GPU programming is not straightforward and architecture-specific optimizations are often required
- Open-source image processing framework is designed
  - GPU/CPU processing with OpenCL
  - Pipelined architecture as an efficient way to hide I/O time
  - Integration with scripting languages using Gobject-introspection
- A chain of filters for parallel-beam tomography has been developed
  - Throughputs of up to 500 MB/s can be handled with a single PC
  - A clustered solution is under development
- A programmable camera is currently under design to enable real-time control
  - Up to 1 Mpix at 5000 frames per second
  - Direct connection to Infiniband cluster
  - Programmable integrated logic for real-time control