

Event-Synchronized Data
Acquisition System of 5 Giga-bps
Data Rate for User Experiment
at the XFEL Facility, SACLA

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SACLA : XFEL facility at SPring-8

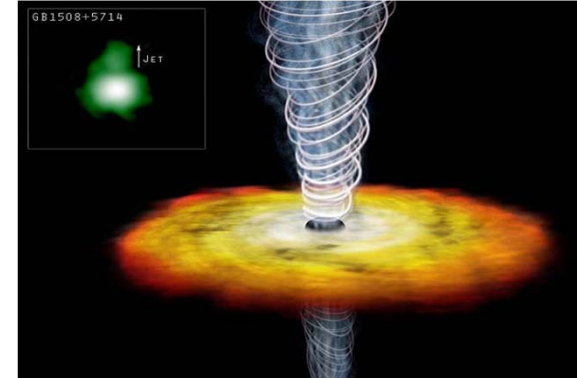
(SPring-8 Angstrom Compact free electron LAser)



- Began operation in February 2011.
 - Aiming for $< 1\text{\AA}$ of wavelength of FEL by 8-GeV linac.
- First lasing achieved on June 2011 at 1.2\AA .
- User experiment will begin on April 2012.

Anticipating a lot of Type of Experiments

Generation of extreme state



High peak brilliance
 $\times 10^9$

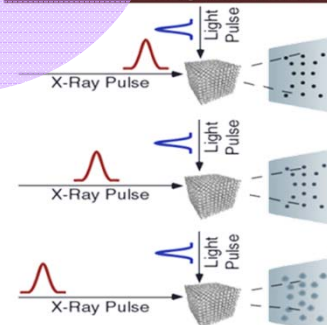
XFEL

Probing of ultrafast
chemical reaction &
phase transition

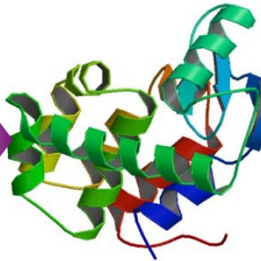
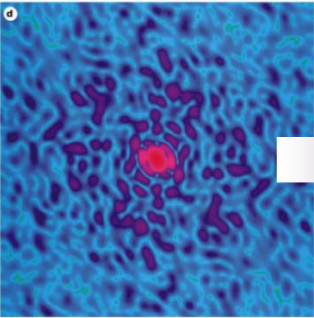
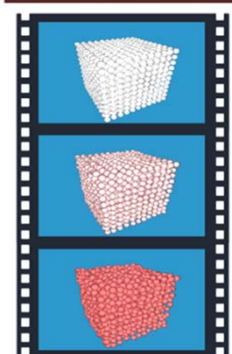
Ultrafast pulse
< 100 fs

Spatial
coherence
100%

Ultrafast X-Ray Diffraction



Movie of
Atomic Movement



Atomic-level imaging for non-crystalline objects

phage

flagella, cilia

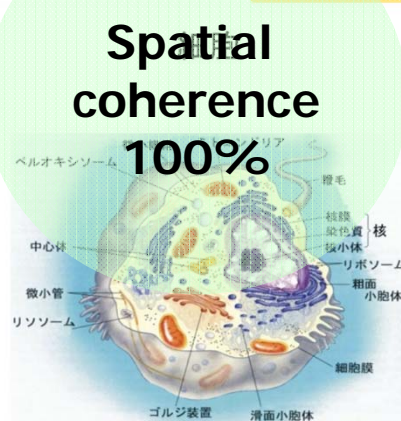
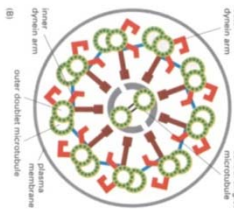
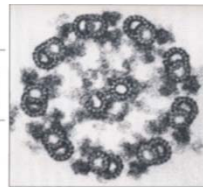
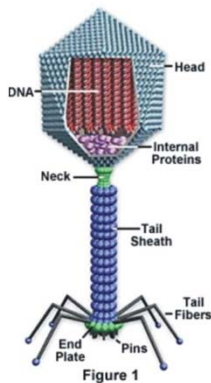
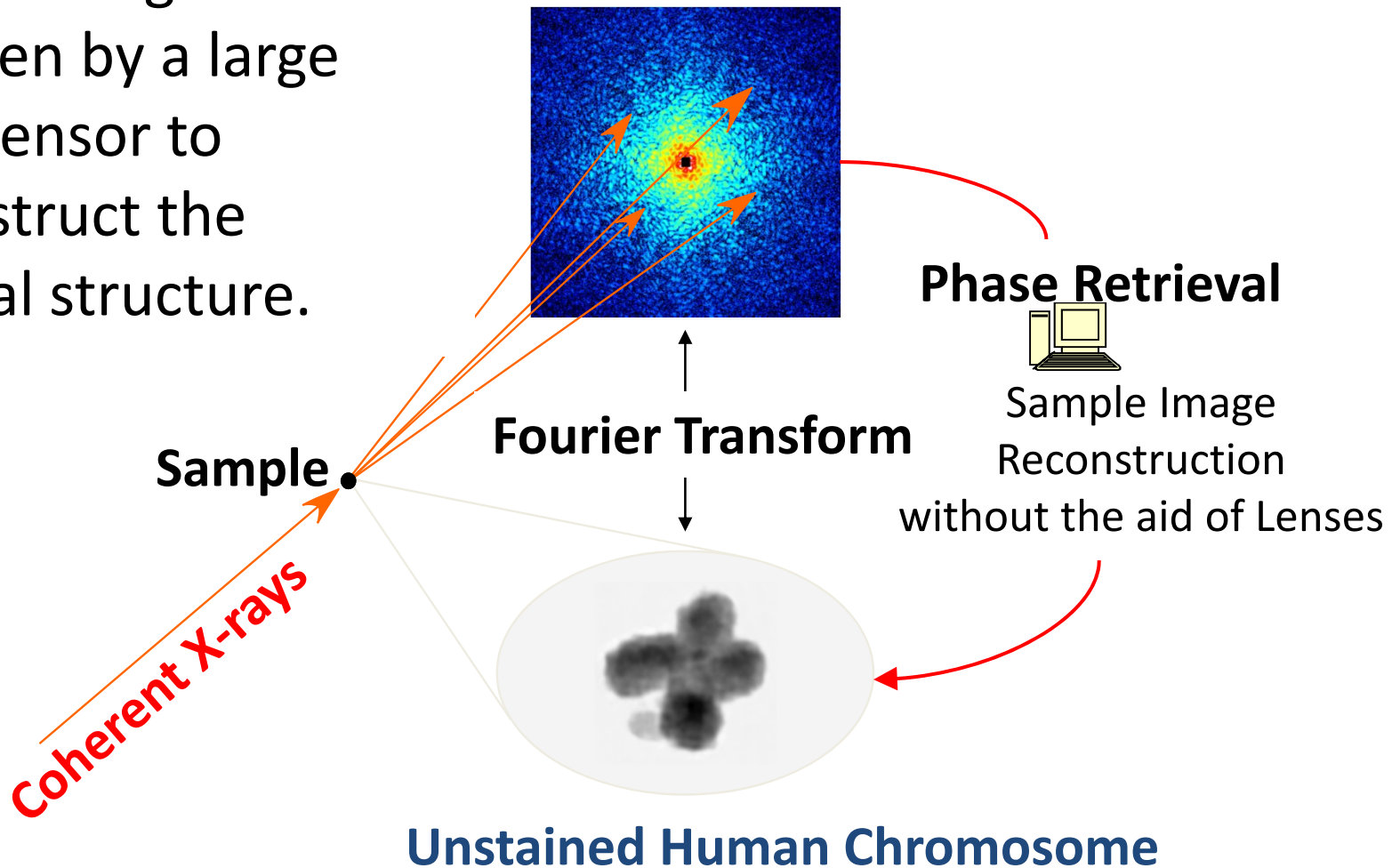


Figure 1

e.g. Coherent X-ray Diffraction Imaging

A lot of images must be taken by a large pixel sensor to reconstruct the original structure.

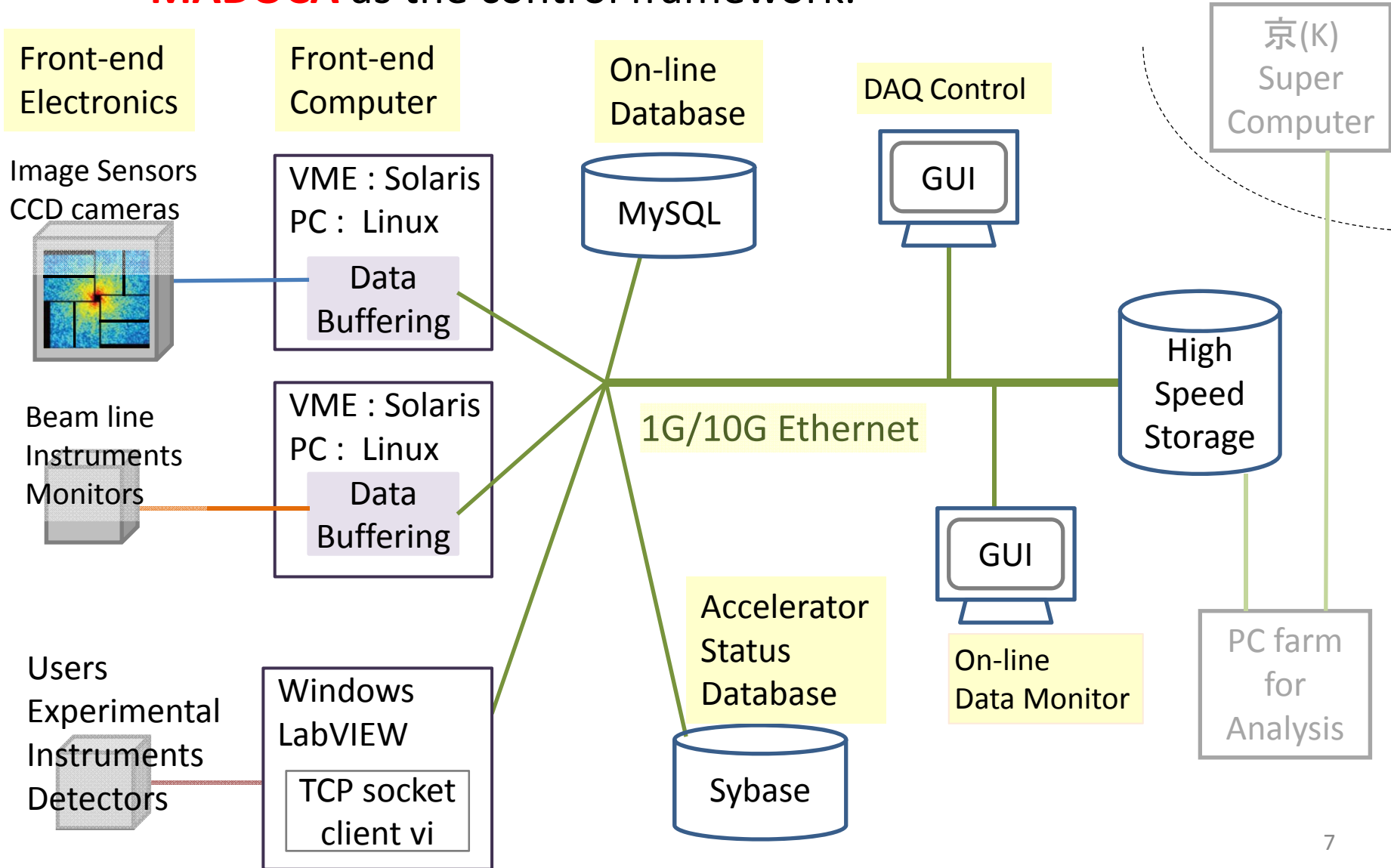


Requirements for Data Acquisition(DAQ)

- *Shot-by-shot* data acquisition in synchronization with the beam operation cycle.
 - In order to correlate the beam characteristics with the data.
 - 60Hz at present, higher for future.
- Accumulate data of large image sensors into storage without data loss.
 - ⇒ *>5 Gbps* of data rate with 6M pixels at 60Hz .
 - Data compression to reduce the bandwidth and storage size.
- On-line data-quality monitor for efficient data collection.
- Any type of users instrument specific to their experiment can be attached to our DAQ to work with.
 - Like a Plug-and-play device.

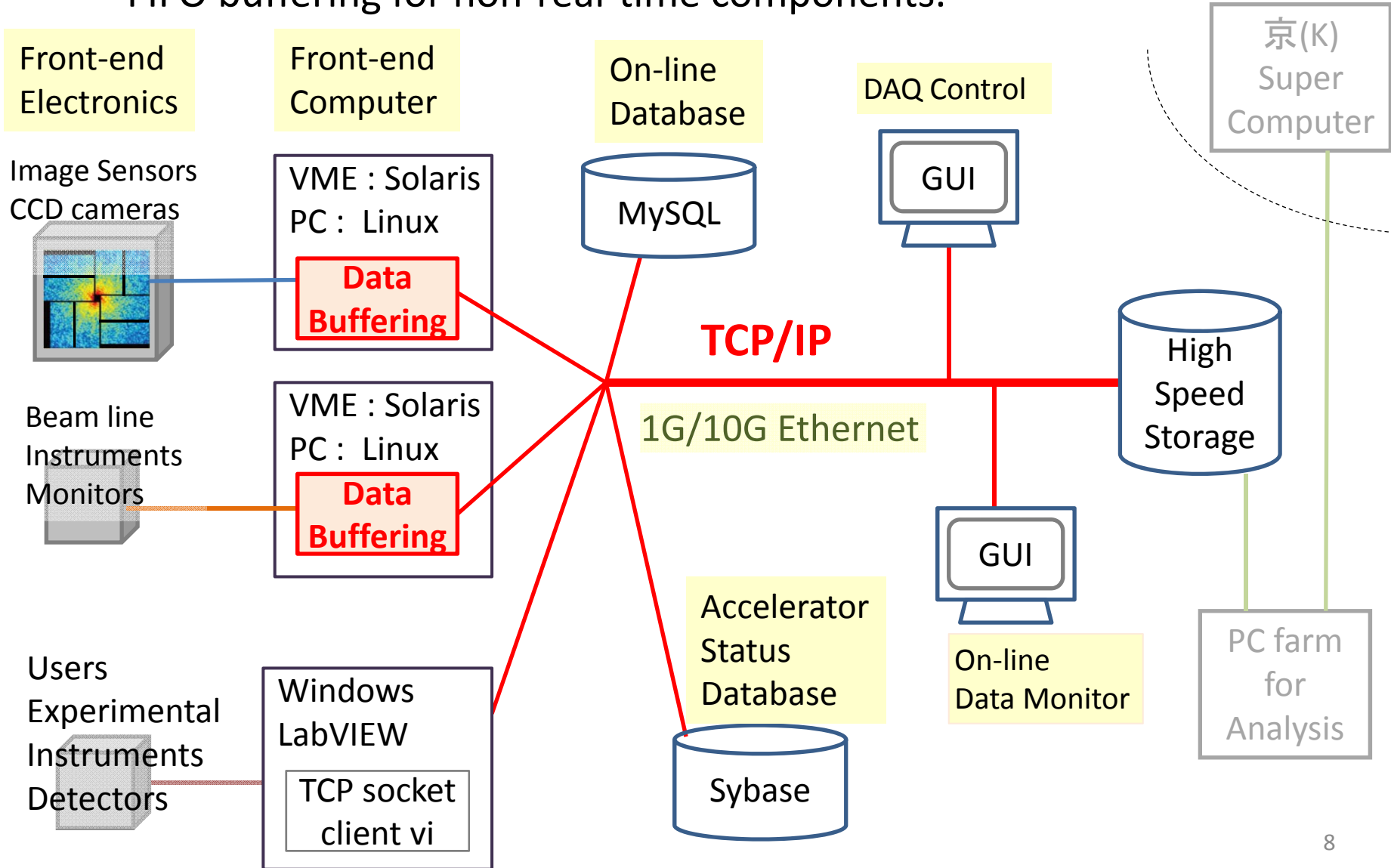
Schematic of DAQ

- Network distributed system.
- **MADOCA** as the control framework.



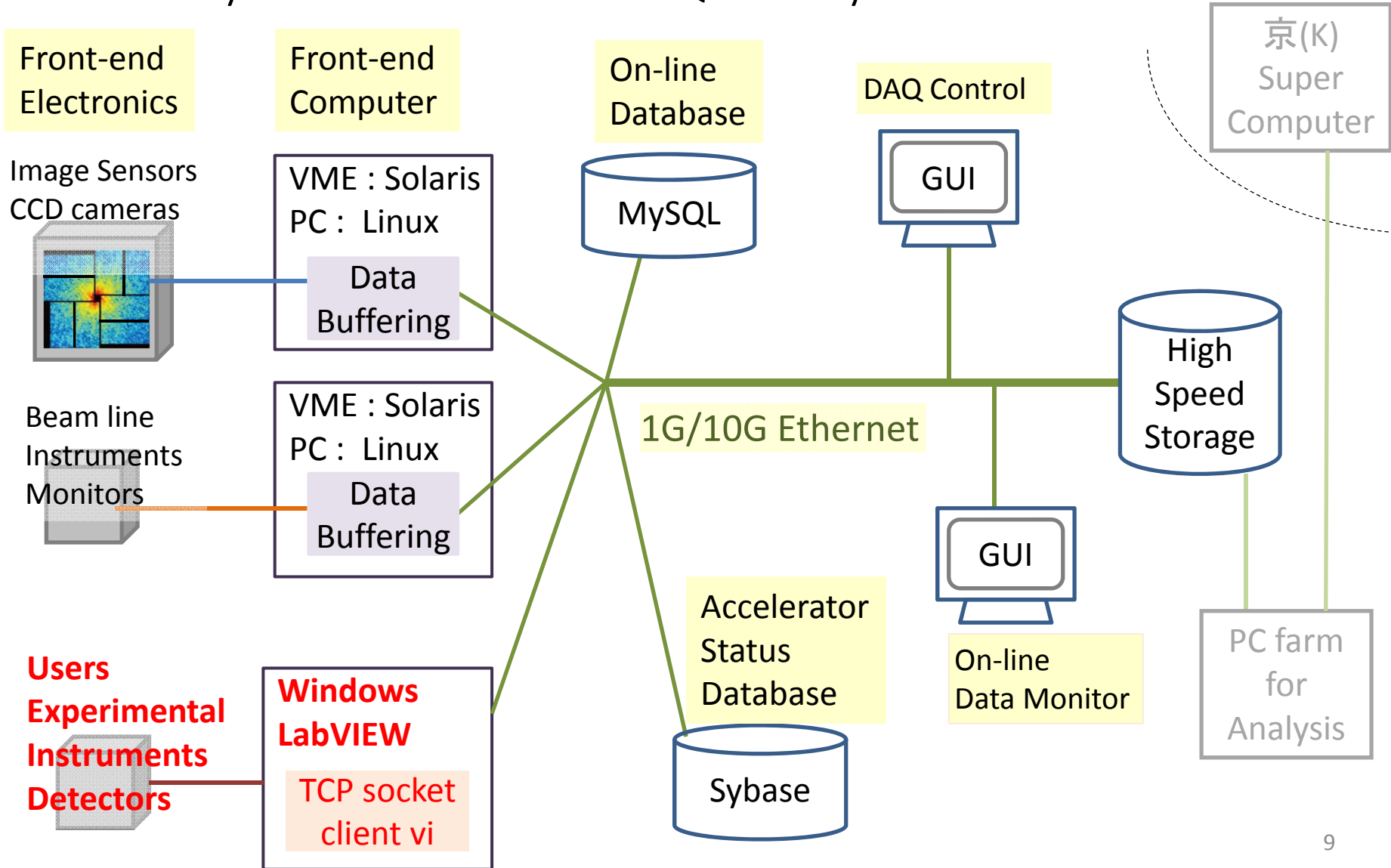
Schematic of DAQ

- Data transfer via TCP/IP over 1- and 10-Gbps Ethernet.
- FIFO buffering for non-real-time components.



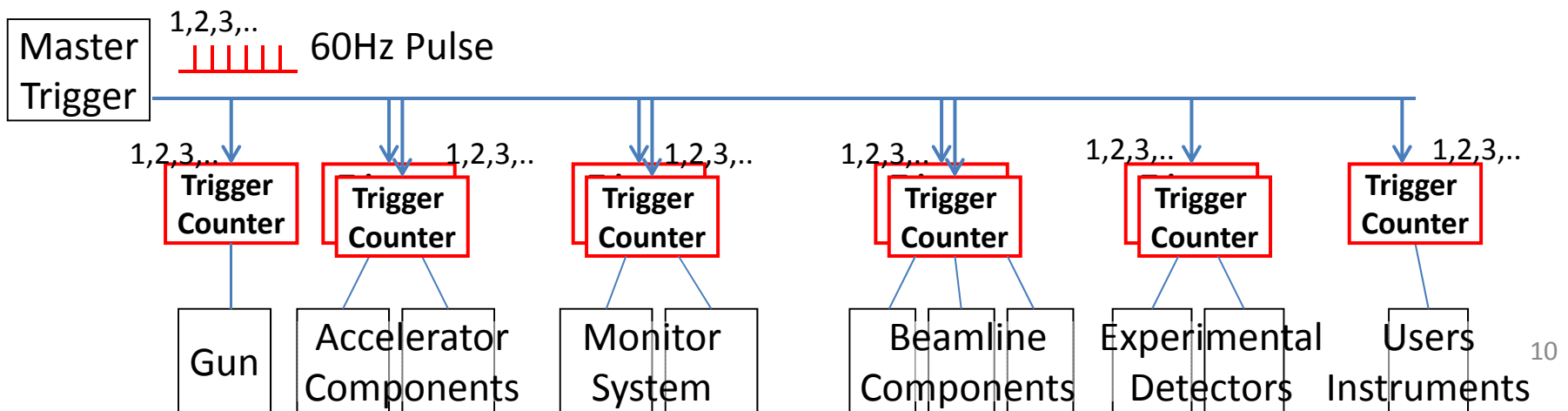
Schematic of DAQ

- Provide TCP socket client module of LabVIEW as a part of our DAQ.
⇒ Easily communicate with our DAQ with only a small modification.



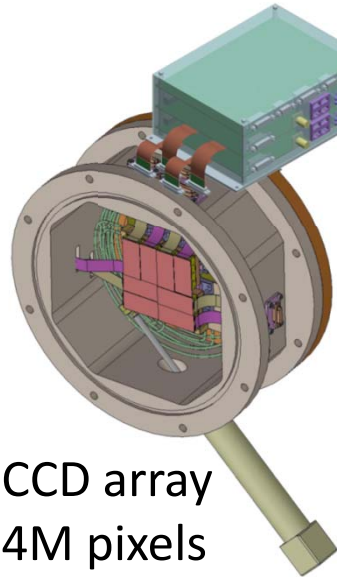
Event Synchronization: Tag Number

- To reconstruct the data set in the same beam shot, a “tag number” is recorded in every data to identify which one is related to which beam shot.
 - Sequential number of master trigger pulse.
 - Counted by the trigger-counter module at each station.
- Delivered to users instruments as well.
 - Encoded serial pulse-train, parallel bit-pattern.



DAQ for Large Image Sensors : >5Gbps

>5 Gbps
in total

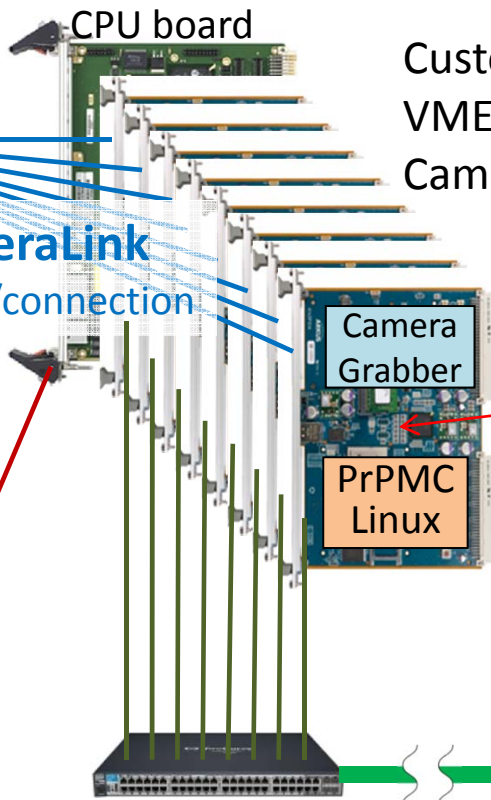


CCD array
4M pixels
60Hz

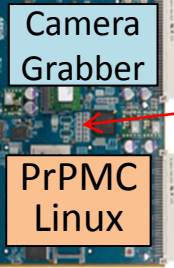
control



CameraLink
> 2Gbps/connection



Custom-made
VME
Camera Link Board



FPGA
Lossless
Compression

10 Gbps Ethernet



Data-handling
Servers



High Speed
Storage



10 Gbps
Ethernet

PC Cluster
Preprocess
10Tflops

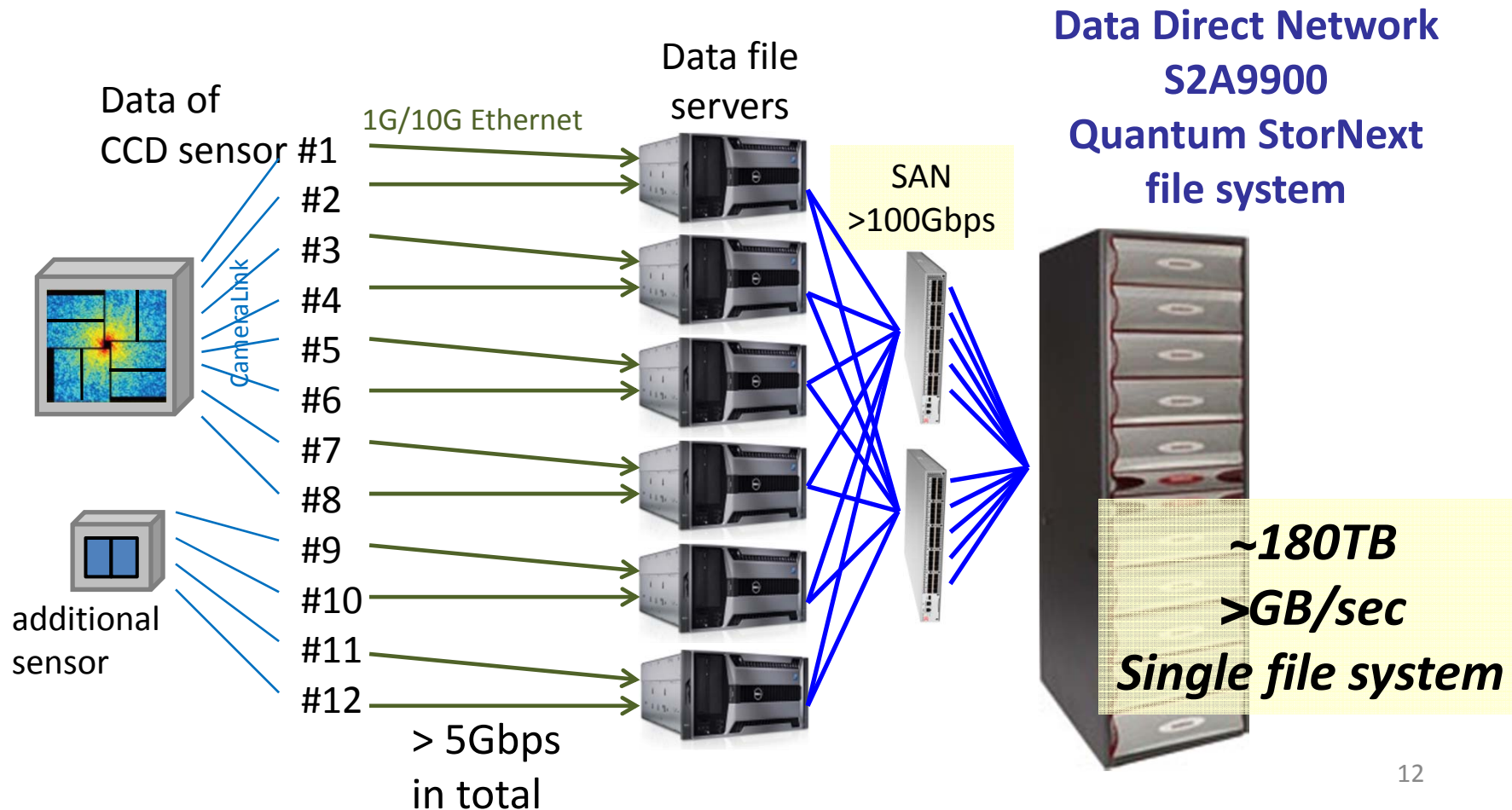


"K Supercomputer"
10 Pflops, 2012.4~



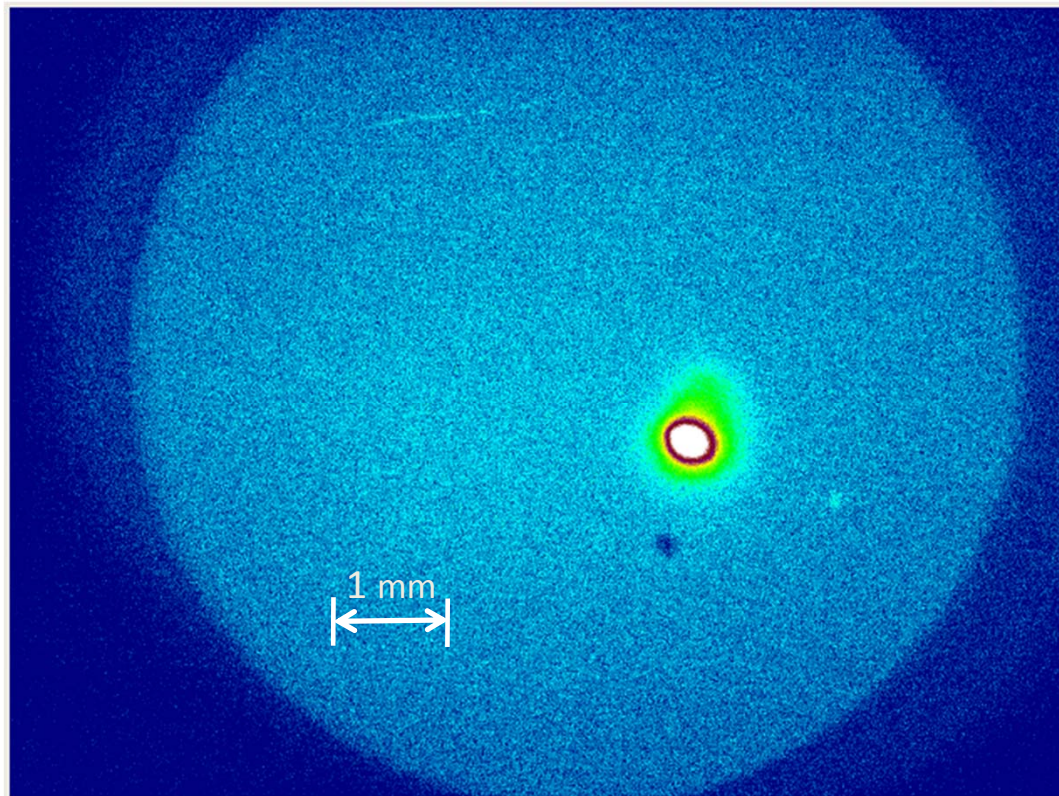
High Speed Storage : DDN + StorNext

- Parallel-writing to a single file system
 - Achieve over 5 Gbps in total.
 - Convenient to handle data files in a centralized repository.



DAQ System Worked as Expected

- Intensively used during beam tuning of SACLA to view the beam profile.
- Ready for user experiments.

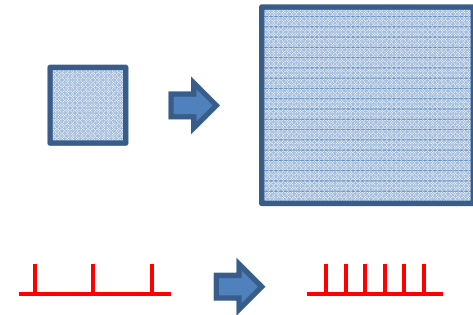


June 7, 2011
First lasing at SACLA
Beam energy: 7GeV
Wavelength: 1.2Å
MPCCD image

Future Prospects

In near future:

- Image sensor: 6M \Rightarrow 76M pixels
 - Beam repetition: 60Hz \Rightarrow 120Hz \Rightarrow 300Hz
- \Rightarrow Data rate ~ x26 : ~150Gbps !
~ x65 : ~380Gbps !



We must find:

- Faster data transfer and storage system
 - RocketIO ? FlexRIO ? ...
 - Distributed storage ?
- Effective data compression / suppression
 - Dedicated algorithm ?
 - Prism ? JPEG2000 ? ...

Ideas, suggestions are welcome.

Summary

- We have constructed an event-synchronized data acquisition system for >5 Gbps of data rate for the SACLA experiment.
 - Shot-by-shot data acquisition up to 60Hz .
 - Expandable for user instruments.
 - ⇒ Ready for user experiments.
- Further upgrades for larger detector size and higher repetition rate will be necessary in future.
 - Faster data transfer and storage system.
 - Effective data compression / suppression.
 - ⇒ Start fighting them.