Beamline Control System of HEPS

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On behalf of Beamline Control Group

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Outline

I. Beamline overview
II. Beamline control system
III. Interface to other systems
IV. Design consideration of BCS
V. Tasks finished in the HEPS-TF
VI. Current status and future work
VII. Summary

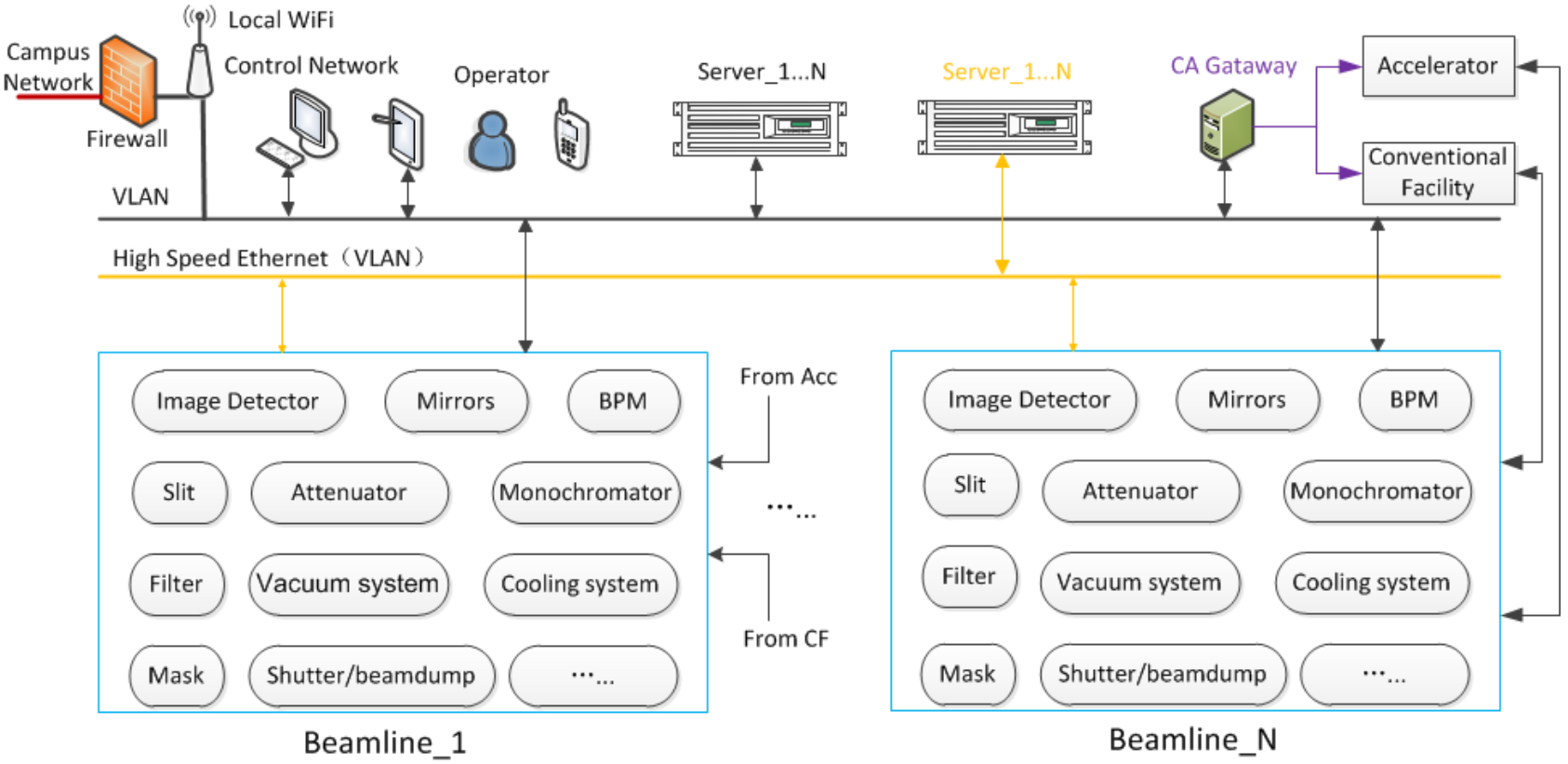
1、Beamline overview

- 14 Beamlines+1 testing beamline

No.	Beamline
1	Engineering Materials Beamline
2	Hard X-ray NAnoprobe Multimodal Imaging (NAMI) Beamline
3	Structural Dynamics Beamline（SDB）
4	Hard X-ray Coherent Scattering Beamline
5	Hard X-ray High Energy Resolution Spectroscopy (HX-HERS) Beamline
6	High Pressure Beamline
7	Hard X-Ray Imaging Beamline
8	X-ray Absorption Spectroscopy Beamline
9	Low-Dimension Structure Probe (LODISP) Beamline
10	Microfocusing X-ray Protein Crystallography Beamline
11	Pink Beam SAXS
12	High Resolution Nanoscale Electronic Structure Spectroscopy (high-NESS)
13	Transmission X-ray Microscope Beamline
14	Tender X-ray beamline

1、Beamline overview

- 14 Beamlines+1 testing beamline



2、Beamline control system

- Principle of beamline control system
  - Stability
  - Availability
  - Reliability
  - Flexibility
  - Extendibility
  - Real Time

2、Beamline control system

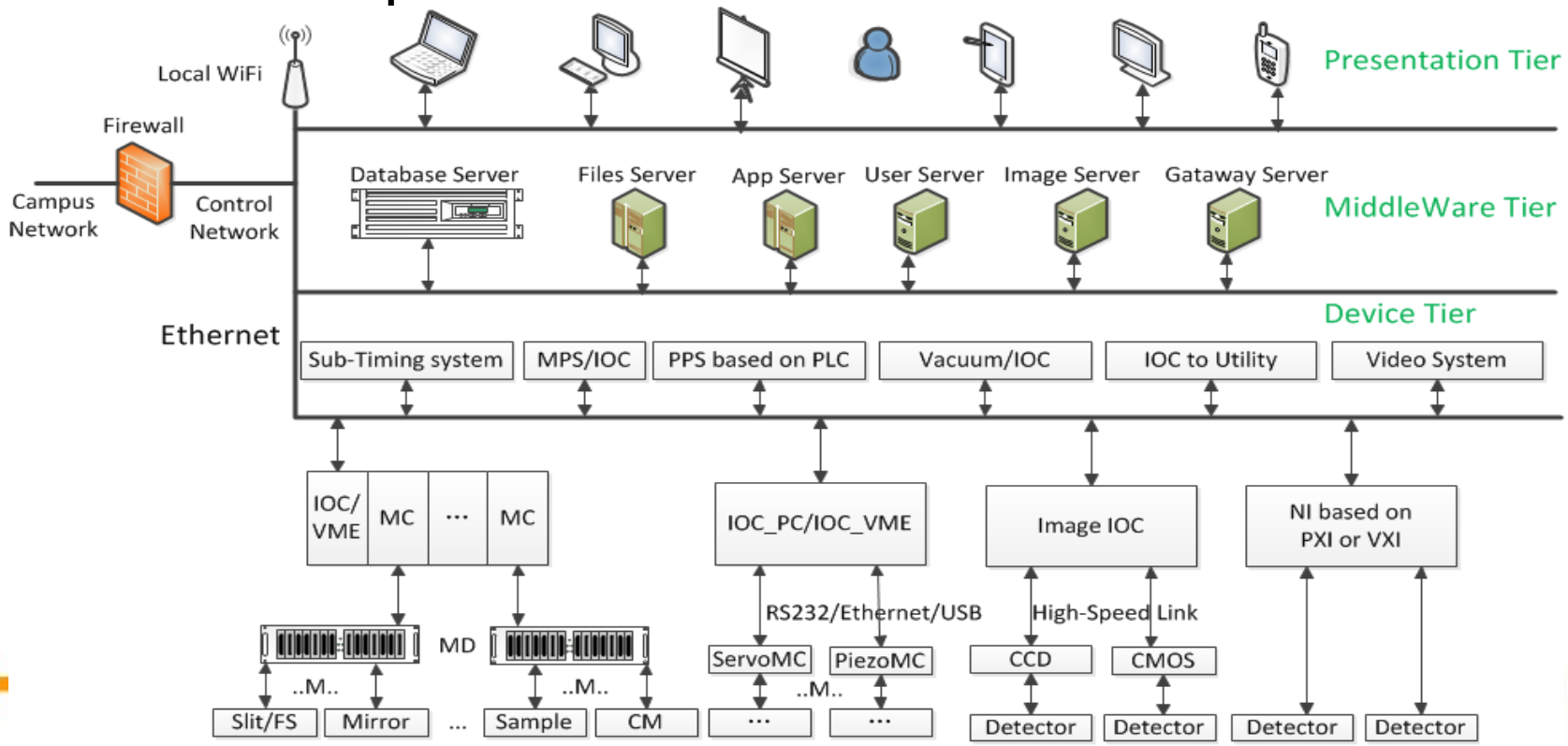
- Tasks of beamline control system
  - To achieve the desired X-ray
  - Ease the scientist at experimental endstations
  - Control and monitor all the equipments of beamlines
  - Detect the position of X-ray beam
  - Protect the people/equipment from hazard, and send alarm and issue information.
  - Provide friendly OPIs, robust and efficient communications tools and rich application tools
  - Archive and retrieve the data of beamline

2、Beamline control system

- Scope of beamline control system
  - Motion control system(including Fly-scan)
  - Beam Position Monitoring system
  - Vacuum control system
  - Cryo-cooling and water-cooling system
  - Data Acquisition
  - Equipment Protection System(EPS)
  - Personnel Protection System(PPS)
  - Timing and Synchronisation
  - *Compute server and network system(IT Division)*
  - Etc.

2、Beamline control system

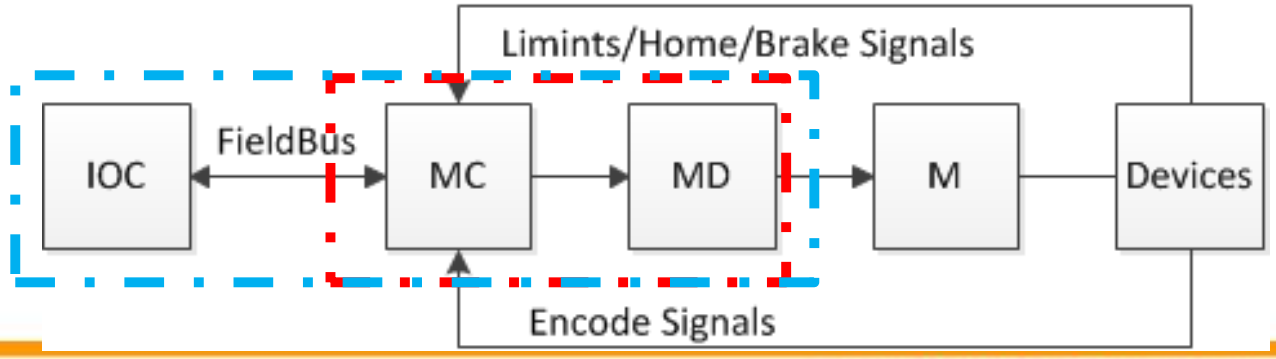
- Beamline control system will be designed and built, based on standardization, modularity and commercial products



The Hardware Architecture of Beamline Control System

2、Beamline control system

- Motion Control System
  - Drive the optical elements(such as: mirror, slit, attenuator, monochromator, filter, etc) to get satisfied X-ray beam.
  - Be critical subsystem of the beamline control system
  - Motor type on a beamline
    - step motor, servo motor and piezo motor



2、Beamline control system

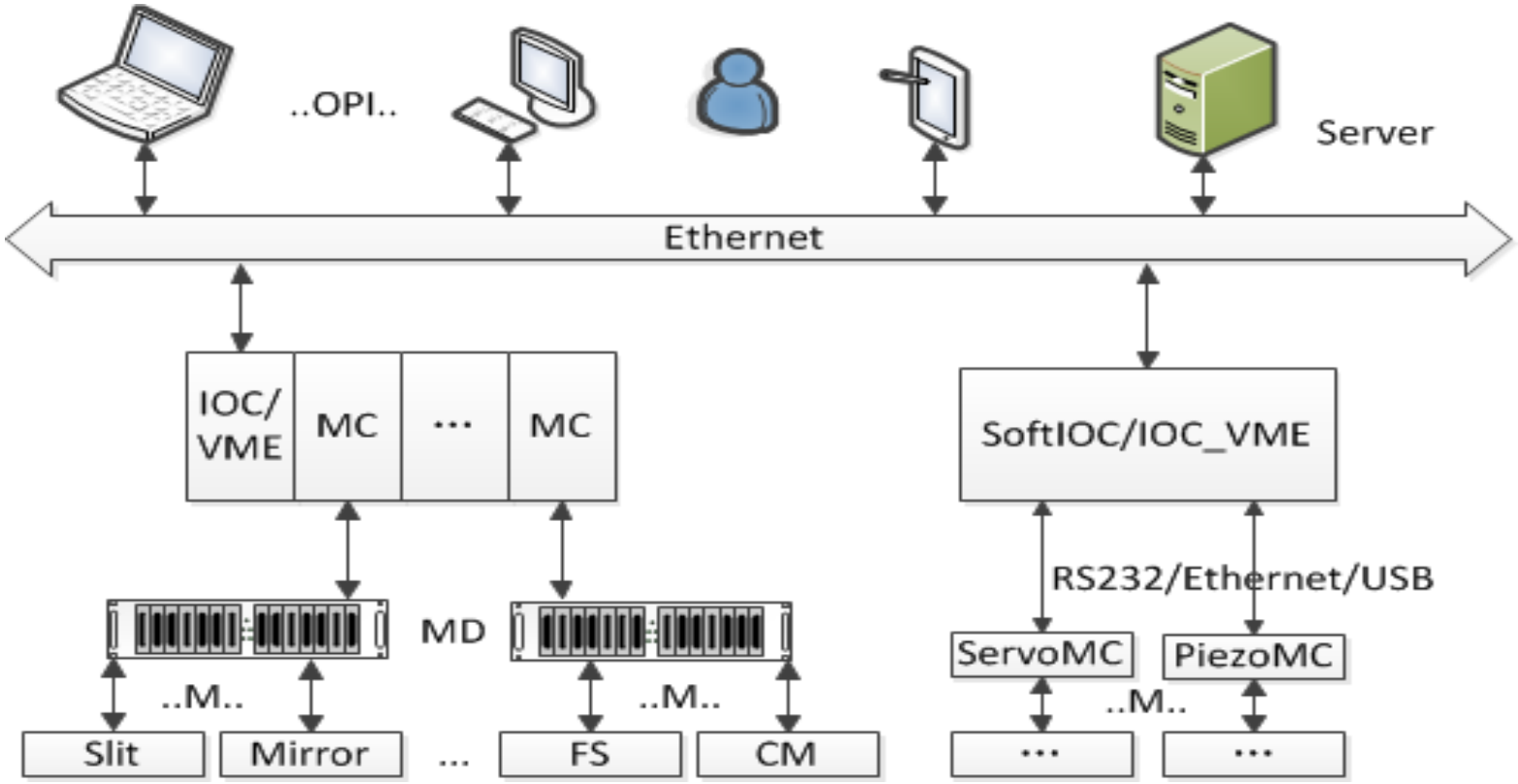
- Motion Control System
  - Control function of motor controller(and driver)
    - ✓Make moves in relative and absolute mode
    - ✓Make a move at a constant velocity
    - ✓Trapezoidal and S-curve velocity profiles
    - ✓Coordinated multi-axis motions
    - ✓Abort a move
    - ✓Adjust velocity, acceleration, and *jerk* for a move

2、Beamline control system

- Motion Control System
  - Control function of motor controller(and driver)
    - ✓Setting of upper and lower *soft* limits
    - ✓Calibration and Selection of homing algorithm
    - ✓Holding current
    - ✓Microsteps per full step
    - ✓Etc.

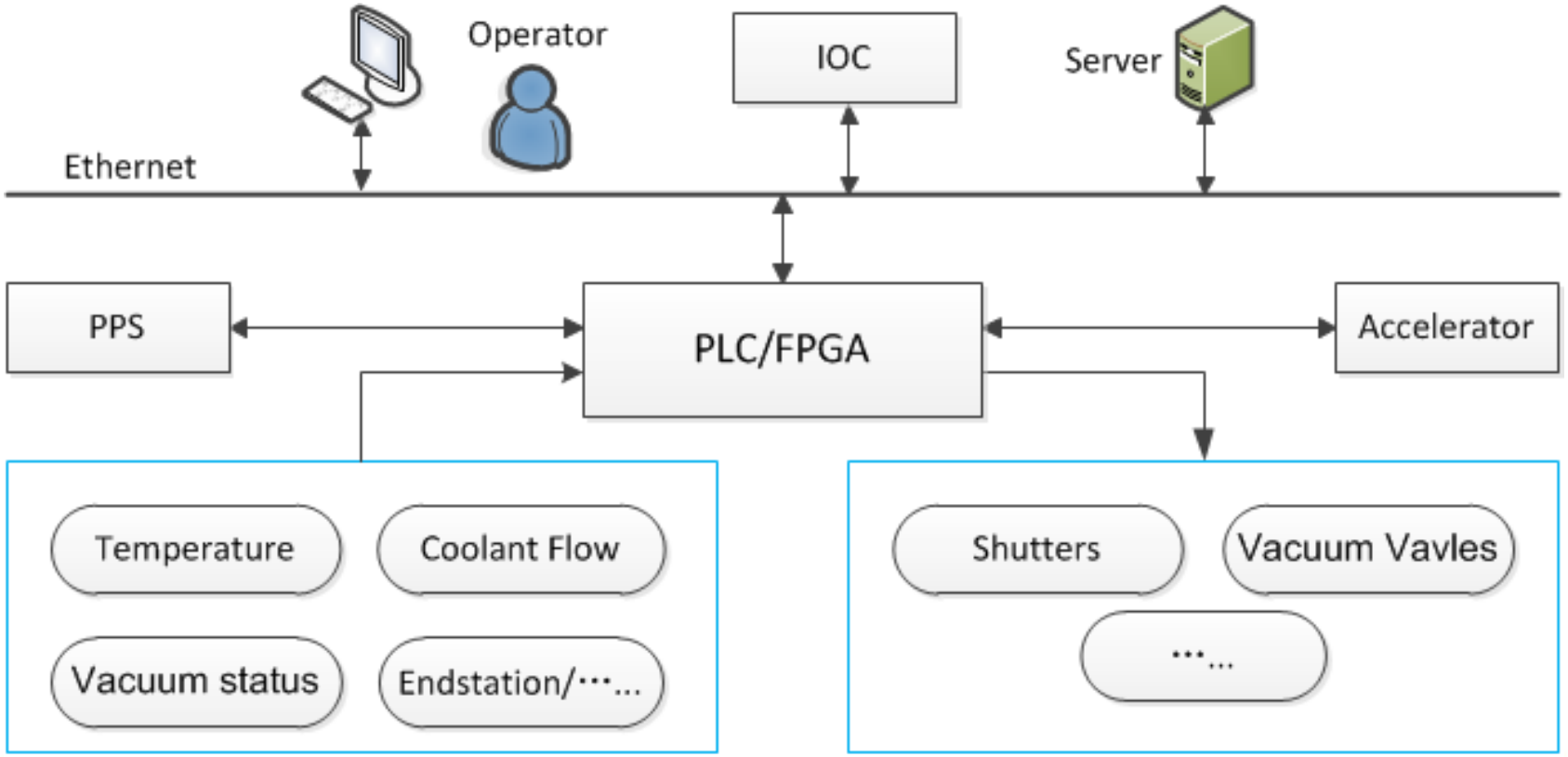
2、Beamline control system

- Motion Control System



2、Beamline control system

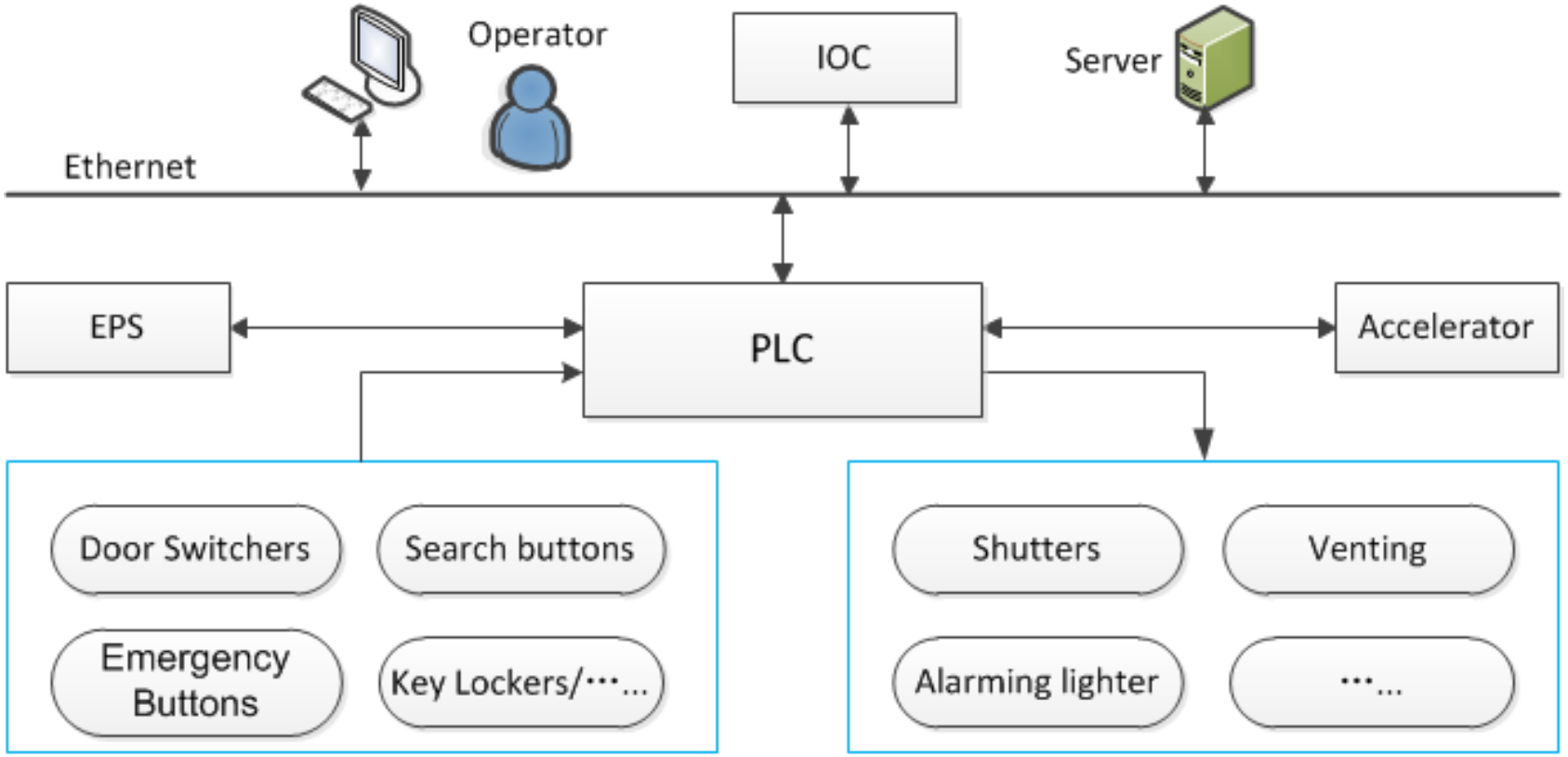
- Equipment Protection System(EPS)



The EPS Architecture of Beamline_X

2、Beamline control system

- Personnel Protection System(PPS)



The PPS Architecture of Beamline_X

3、Interface to other systems

- Interface to accelerator control system
  - Insertion Device (undulator/wiggler)
  - Machine Protection System
  - Personnel Protection System
  - Timing system.
    - Storage ring revolution clock.
    - Injection signal
    - RF clock to some stations
  - Get information from accelerator, such as beam current, beam mode, etc.

3、Interface to other systems

- Interface to conventional facility system
  - Flow of water-cooling system
  - Temperature(water, environment)
  - Pressure(cooling water, compressed air)
  - Power status
  - Etc.

4、Design consideration of BCS

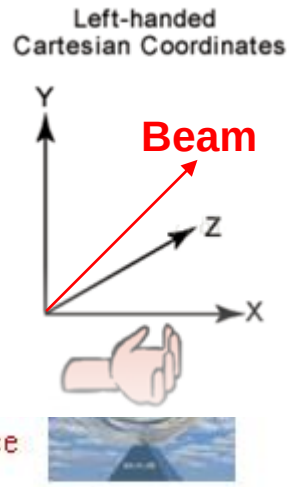
- PV naming convention
- The coordinate system convention
- Hardware
- Software

4、Design consideration of BCS

- PV naming convention
  - Each PV has an unique name in beamline control network
  - Rules of PV name are almost consistent with the accelerator's naming convention
  - System and device hierarchies allow flexibility in naming

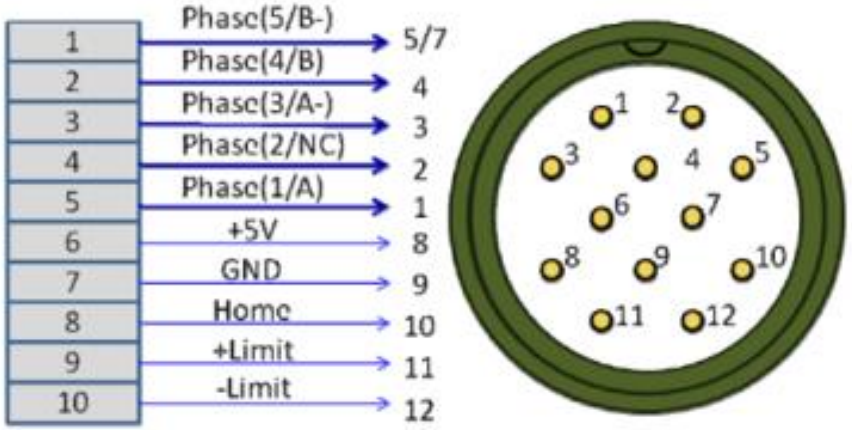
4、Design consideration of BCS

- The coordinate system convention
  - The coordinate system convention follows a left-hand rule
  - The positive z-axis is parallel to the direction of x-ray beam propagation
  - The y-axis is positive in the vertical direction towards the ceiling
  - Standard definition of cartesian and rota axes



4、Design consideration of BCS

- Alternative Hareware
  - VME_CPU
  - VME_Crate: 7/21 slot
  - Motor Controller/Driver
  - PLC: Yokogawa/Allen Bradley/Siemens/domestic PLC
  - Transition board: one for eight
  - Electrical cable
  - Etc.

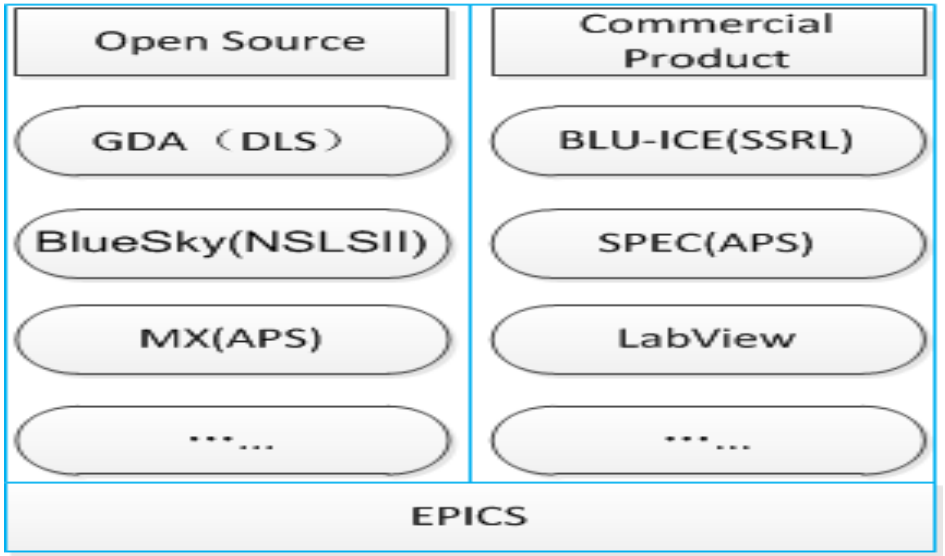


4、Design consideration of BCS

- Software
  - OS: Linux
  - OPI:CSS(-->Phoebus), EPICS Qt
  - EPICS/synApps modules
    - Motor, Transform, Sscan, busy
    - AreaDetector
    - Optics
    - Autosave
    - devIocStats
    - etc

4、Design consideration of BCS

- Software
  - Experimental endstation software



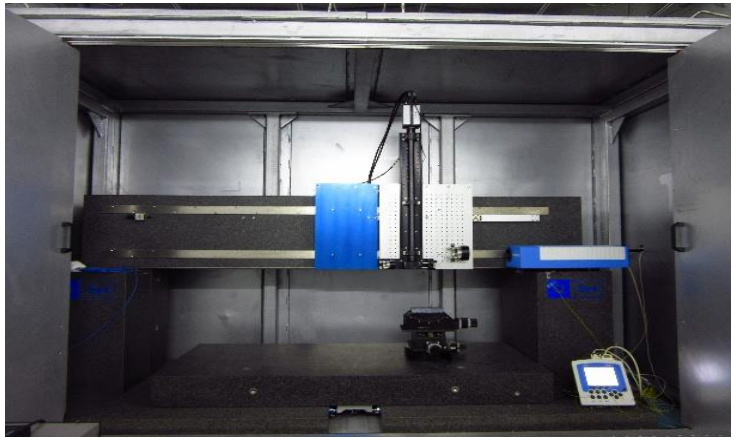
  - Evaluate and select it with beamline scientists

5、Tasks finished in the HEPS-TF

- Control of Long Trace Profiler (LTP)
- Control of the bending focusing mirror
  - Control of the Long Bending Focusing Mirror
  - Control of the K-B Bending Focusing Mirror
- Cryogenic control of Monochromator with liquid nitrogen

5、Tasks finished in the HEPS-TF

- Control of the Long Trace Profiler
  - The LTP is a high accuracy optics profile detection instrument
  - Measure high accuracy slope trajectory in a long optical surface



LTP---Long Trace Profiler

Based on: Scan detection

Scan area:1.5m*0.3m

Positional Accuracy： 1um

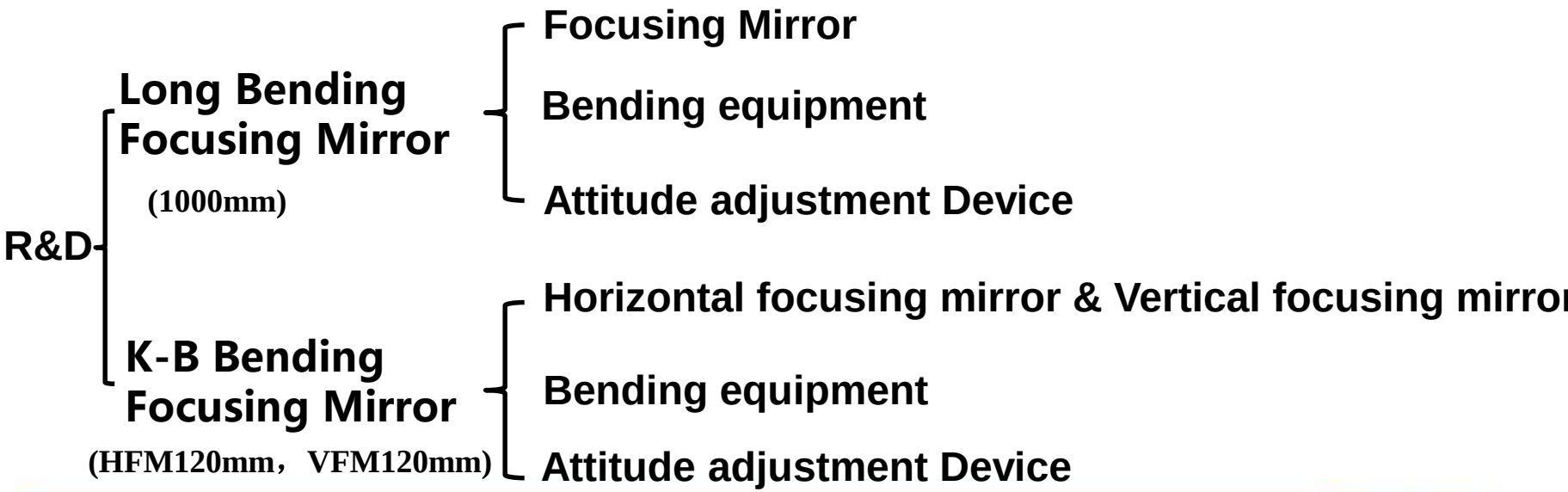
Andor camera:

Image pixels: 2048 * 2048

Physical pixel: 6.5um*6.5um

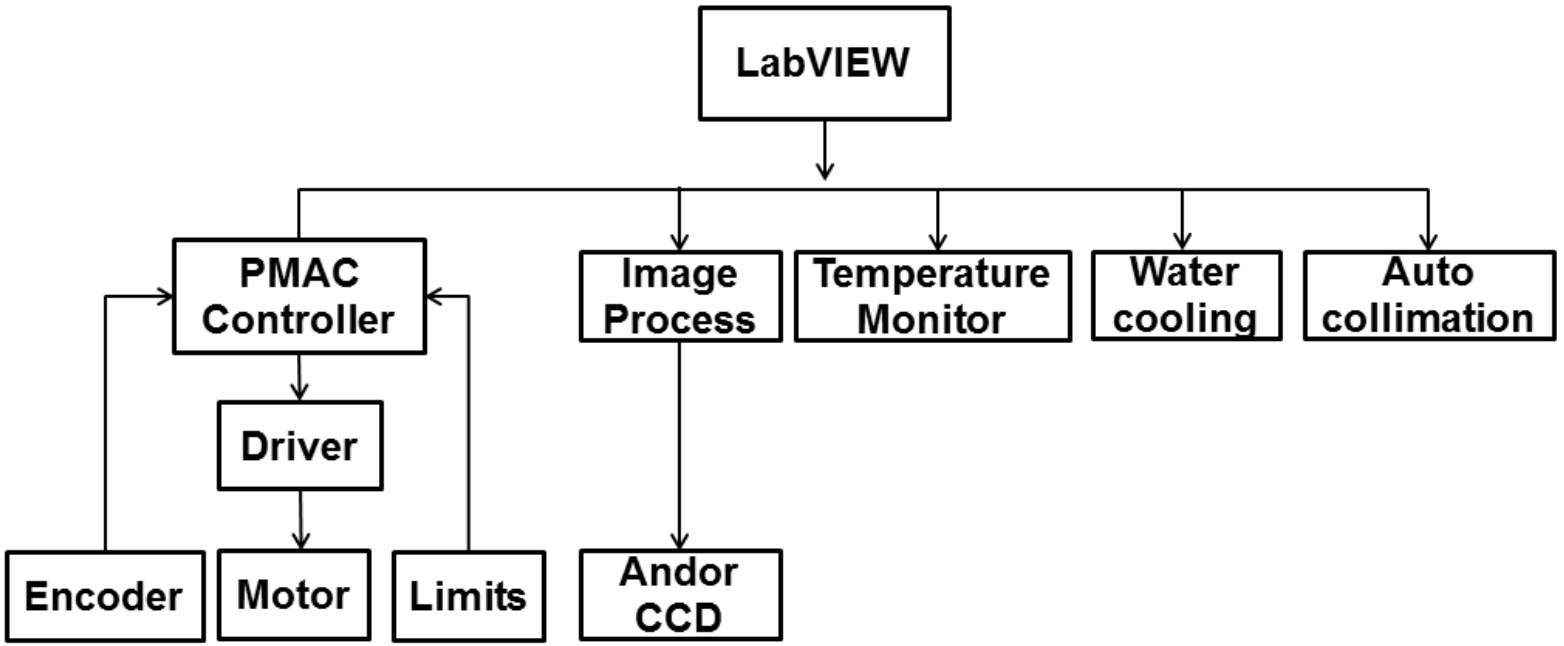
5、Tasks finished in the HEPS-TF

- Control of the bending focusing mirror(BFM)
  - BFMs are critical components
  - High profile accuracy at low cost
  - Adjusted and corrected easily



5、Tasks finished in the HEPS-TF

- Control of the Long Trace Profiler(LTP)
- Control of the bending focusing mirror(BFM)



The control structure of LTP(BFM)

5、Tasks finished in the HEPS-TF

- Cryogenic control of Monochromator with LN

Working condition
- Used as first optical component
- High thermal load
- High thermal power and power density deform the crystal

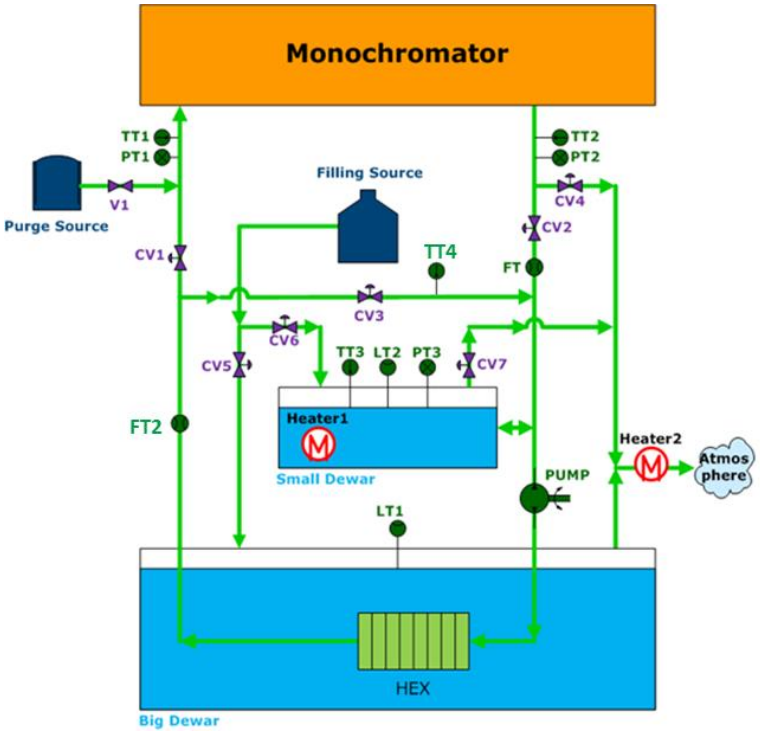
Performance
- Fine resolution of homogeneous X-ray energy
- High flux on sample
- Smaller crystal deformation

Monochromators are cooled by LN

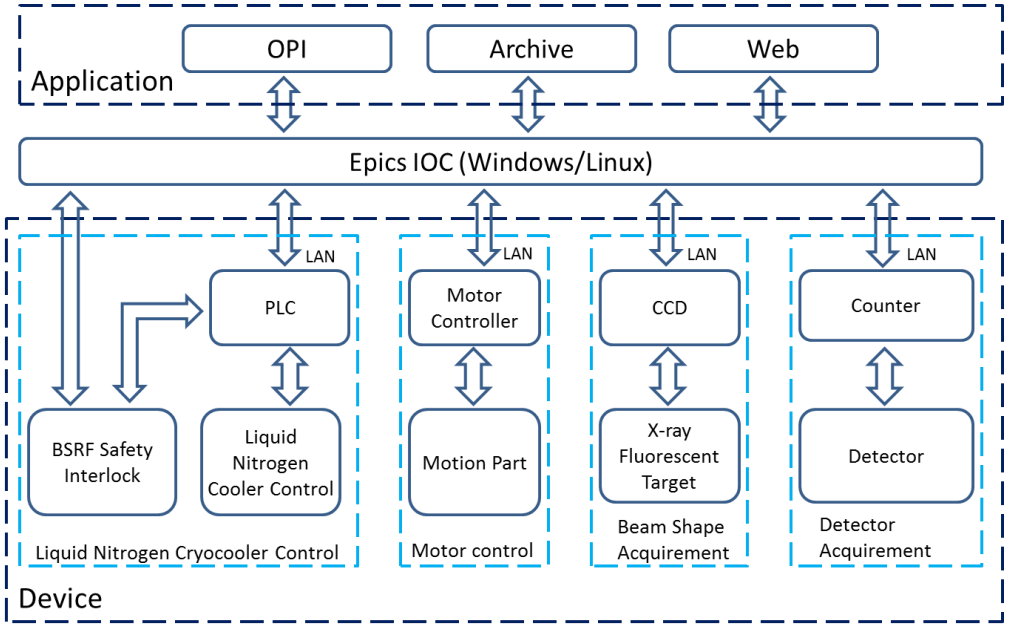
Items	Technique Specification
Energy range (keV):	5~20
Crystal：	Si（111）
Accuracy of X-ray export height (mm)：	±0.1
expand of rocking curve caused by thermal load	<10%
Thermal power received by crystal（W）：	<800
Peak of thermal power density received by crystal（W/mm^2）：	<10
Cryogen:	Liquid Nitrogen（77K）
Static vacuum（Pa）：	<10^{-4}
pressure fluctuate in small dewar	≤±1.5KPa

5、Tasks finished in the HEPS-TF

- Cryogenic control of Monochromator with LN



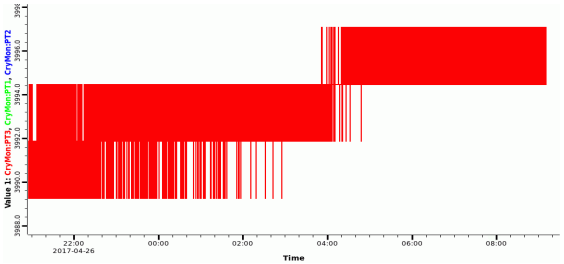
Flow chart of Monochromator with LN



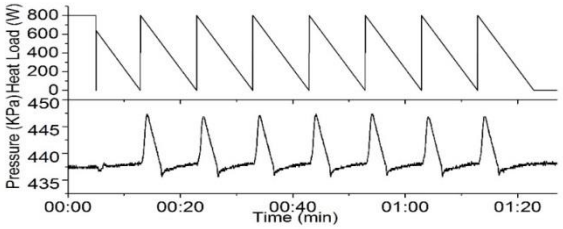
The control structure of Monochromator with LN

5、Tasks finished in the HEPS-TF

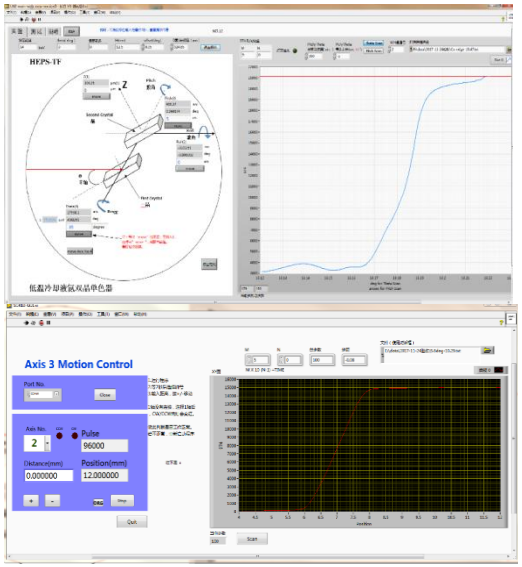
- Cryogenic control of Monochromator with LN
  - ✓ Offline: test at 15# experimental hall
    - ➢ Pressure < ± 0.55Kpa @ 4bar in small dewar
  - ✓ Oneline : test in 3W1 Beamline at 13# hall
    - ➢ Cu absorption edge is measured



Offline: Pressure fluctuate in 12 hours



Offline: Pressure chart with 800W Heat load triangular wave variety



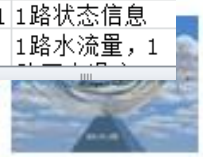
Online: Motor control GUI

Offline test in BSRF 15# experimental hall

6、Current status and future work

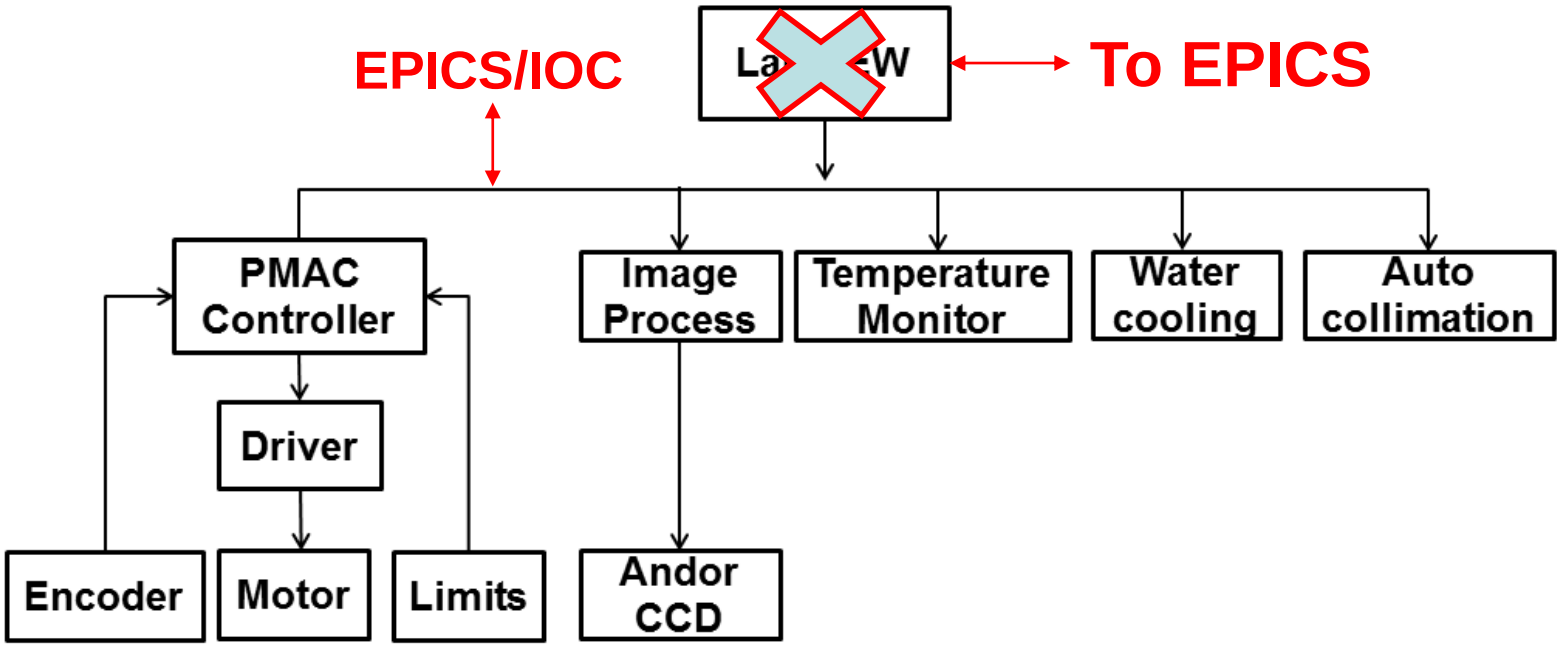
- Preliminary control requirements have been done

备注	设备	到光源距离m	区域划分	电机类型	电机轴数	调节类型	其他信号数	其他信号类型	数量
前端区	扁管	30.1—32.1							2
	闸板阀	31.8							2
	三通管（三通泵）	32.1							2
	波纹管	32.2—32.5							2
	固定光阑	32.6							2
入口金刚石窗	金刚石窗	32.7							1
	白光吸收片	33.5		步进电机+编码器	4	4轴垂直	6	1路水流量，1路回水温度，4路状态信息(是否在光路中)	2
	波纹管	34.0—34.2							1
	侧接离子泵1	34.2							2
	波纹管	34.2—34.4							1
	白光BPM1	34.5		步进电机+编码器	3	2轴扫描，1轴垂直	4	4路电流信号	1
	波纹管	34.6—35.0							2
	Mask	35.0							1
	波纹管	35.0—35.2							1
	钨致辐射准直器	35.5							1
	波纹管	35.8—36.4							7
	白光荧光靶1	36.5		气动	1	1轴垂直	2	1路状态信息，1路视频信号	
	侧接离子泵2	36.5							
	波纹管	36.6—36.8							
	插板阀1	36.8		气动	1	1轴气动 1轴镜箱平	1	1路状态信息 1路水流量，1	



6、Current status and future work

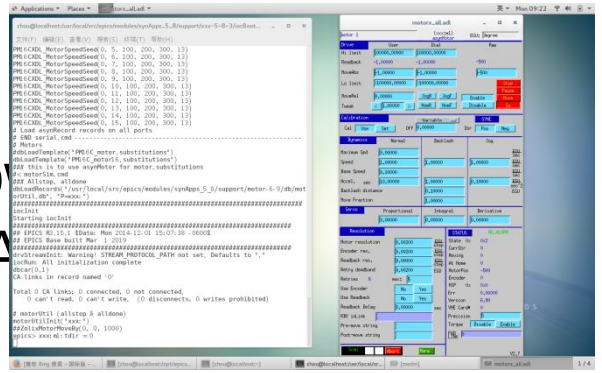
- Integrate Labview-based control tasks into EPICS



The control structure of LTP(BFM)

6、Current status and future work

- Prototypes of BCS will be built
  - Motion control system
    - Investigation: Geo Brick LV(→Po
      (used in NSLSII,DLS), VME58/MA
      APS,CLS,SSRF), PM16C(BSRF)
    - Goal: the standard motion control module
  - Data acquisition
  - Interlock system based on PLC(EPS/PPS)



6、Current status and future work

- Man power
  - New team formed in April 2018, from 4 to 8 people eventually
    - 4 from accelerator division
    - 4 from beamline division
  - Recruit 2~3 in the coming year

6、Current status and future work

- Collaboration and training
  - Plan: cooperate closely with other synchrotron complex (SSRF, Spring8, DLS, NSLSII, ESRF, etc)
    - Invite experts from other similar beamlines to train/support
    - Send members of control team members to existing similar facilities to learn/exchange

6、Current status and future work

- Collaboration and training
  - Work tightly with beamline scientists
    - Ensure all control requirements are clearly defined and understood
    - Specific requirements will be detailed more separately for each of the beamline
    - Identify the difficult applications and solve them as soon as possible

7、Summary

- Requirements have been discussed with beamline scientists
  - Clarify basic control requirements
  - Budgets have been estimated
- Methods toward standardizations have been studied
  - to make the rapid development and easy maintenance
- Beamline control techniques have been investigated and discussed
- Prototypes will be built
- Share design idea and software/FPGA experience with accelerator control of HEPS
  - EPICS, PLC, PPS, MPS and so on
- Hope to get collaborations with other labs
  - Share/reuse experience/work done in other facilities

Huairou District, Beijing

Thanks for your attention

There are many difficulties. Hope lies in it.

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