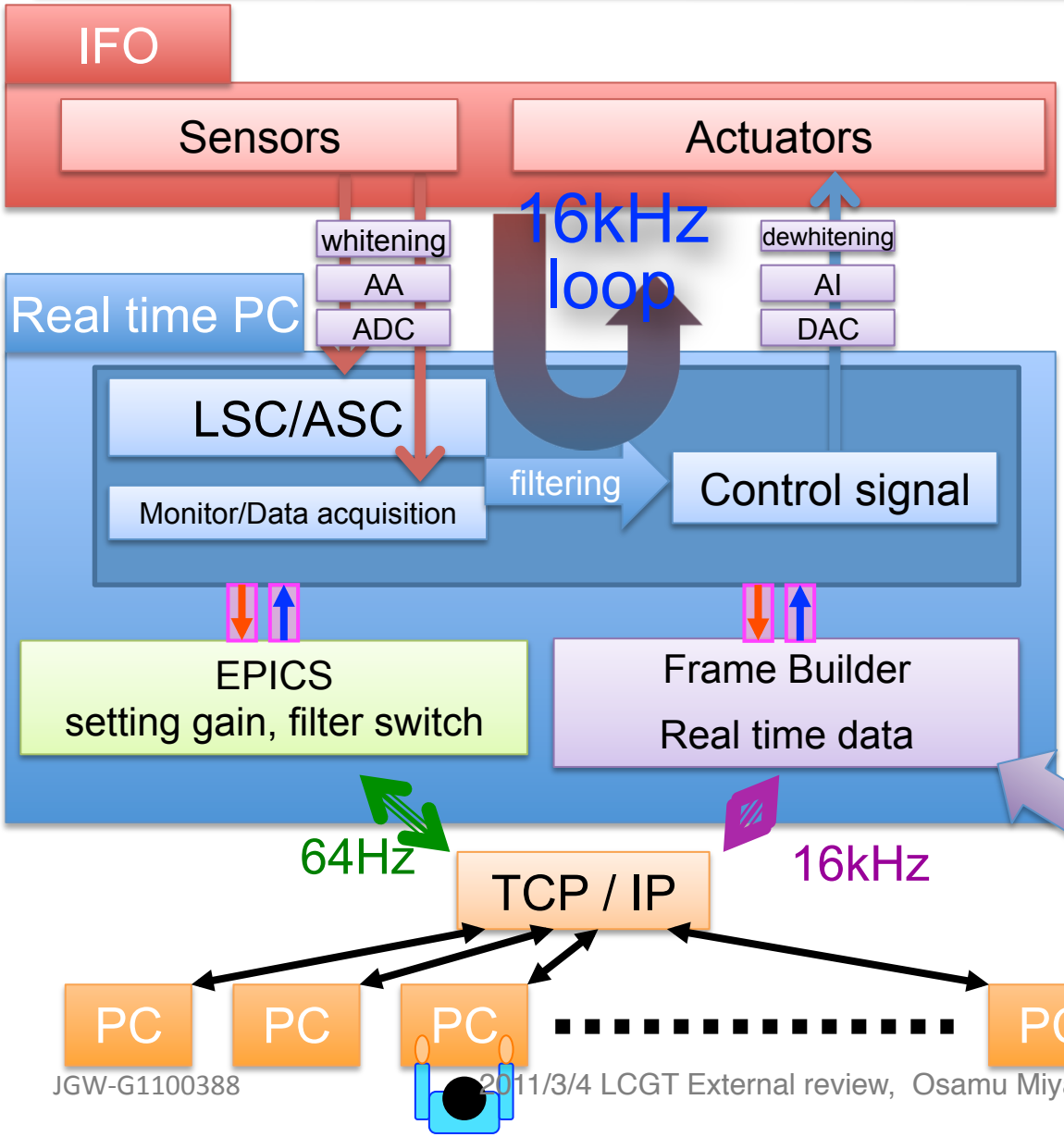
# Concept of the digital system




- Provides a very flexible human interface to the complex DOFs of the interferometer.
- Functions as sensing, control, monitor, switch
- Good solution to treat huge numbers of signals

# Global and internal requirements

## Global requirements

- Observation bandwidth >5kHz
- Dynamic range >120dB
- Control bandwidth >200Hz
- Number of channels >1024
- Number of output channels >256

## Internal requirements

| Item | Requirements | Comment |
|---|---|---|
| Sampling rate | >=16384Hz | 65536Hz at ADC, then decimated to 16384Hz |
| ADC bit resolution | >=16bit | |
| Dynamic range of input | >=+/-15V | Differential input |
| Dynamic range of output | >=+/-10V | Differential output |
| ADC noise | <3uV/rHz | Effectively reduced by whitening filter |
| DAC noise | <3uV/rHz | Effectively reduced by dewhitening filter |
| time delay | <100usec | For >200Hz UGF |
| Input channel numbers | >2048ch | (16kHz:>128ch, 2kzHz:>512ch, 64Hz>1024ch) |
| Output channel numbers | >512ch | For mirrors, seismic attenuators, PZTs etc. |
| Stored channel numbers | 16kHz:>64ch, 2kzHz:>512ch, 64Hz>1024ch, 16Hz>10000ch | ~300TB/year |

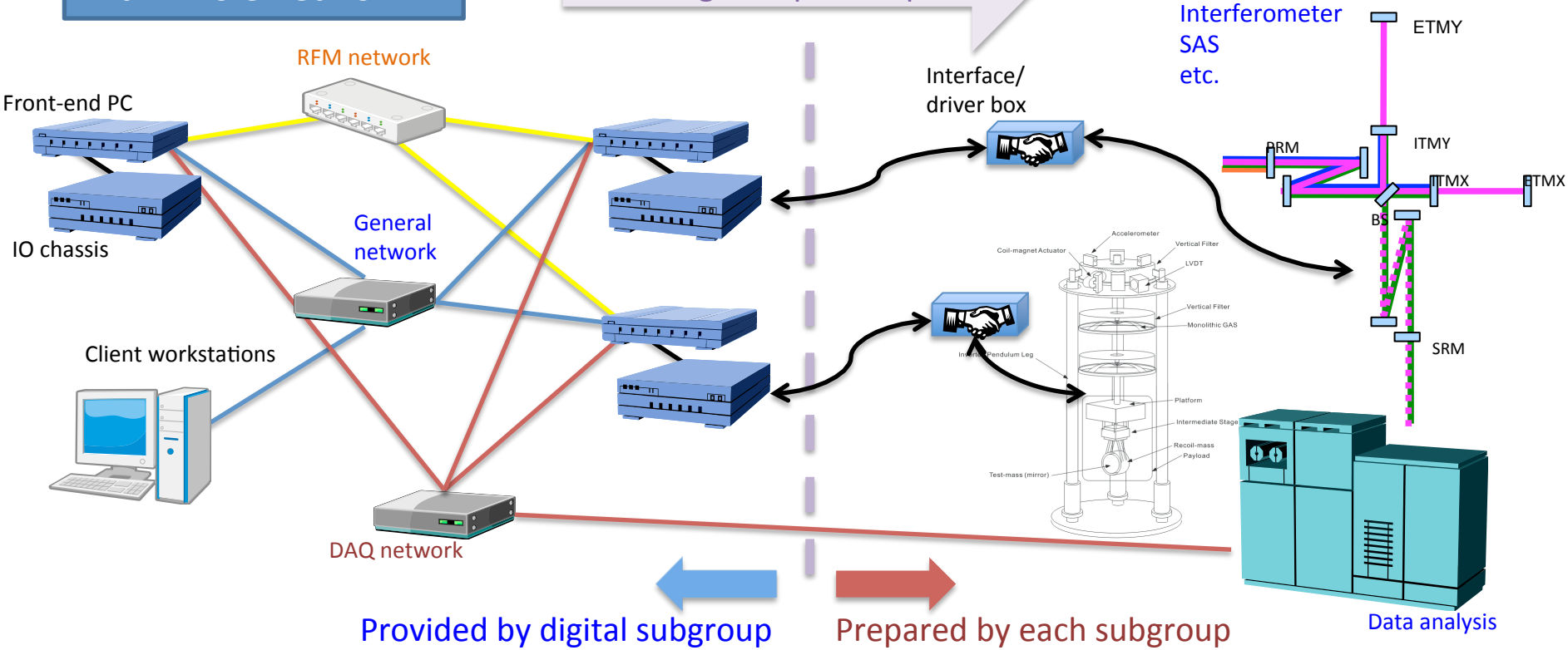
Provides a robust and flexible platform to IFO and all subsystems for control, monitor, diagnostic, switch during installation, commissioning, operation, observation

# Overview of digital system subgroup

Building digital system with whole network

Providing a platform for signal input/output

Application



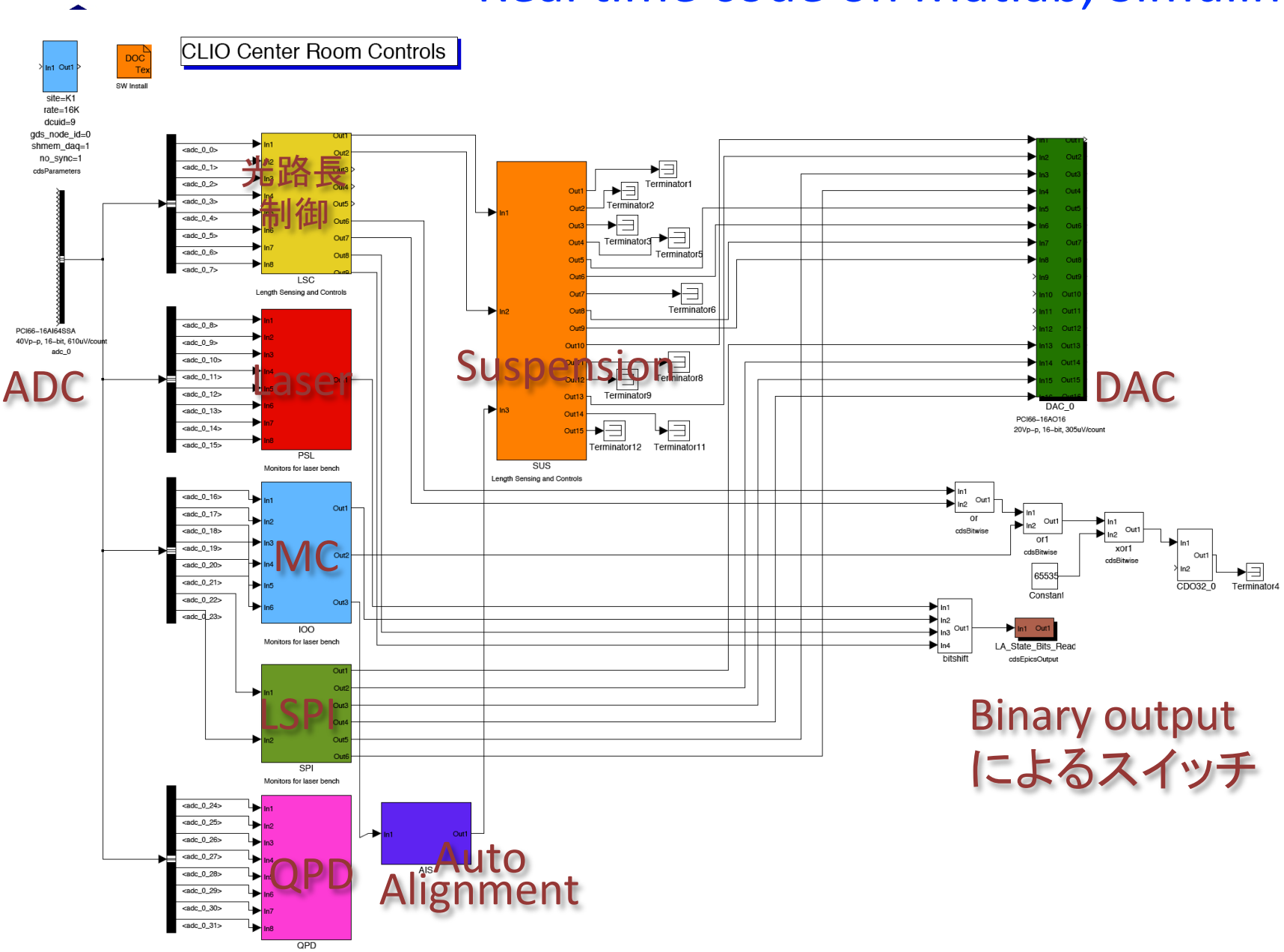

- Real time system
- PC, software
- ADC/DAC/BO, AA/AI
- DAQ/RFM/timing network

- Control, monitor, switch
- Auto lock, auto alignment
- Commissioning, noise hunting
- Diagnosis, tuning, calibration
- Operation, observation

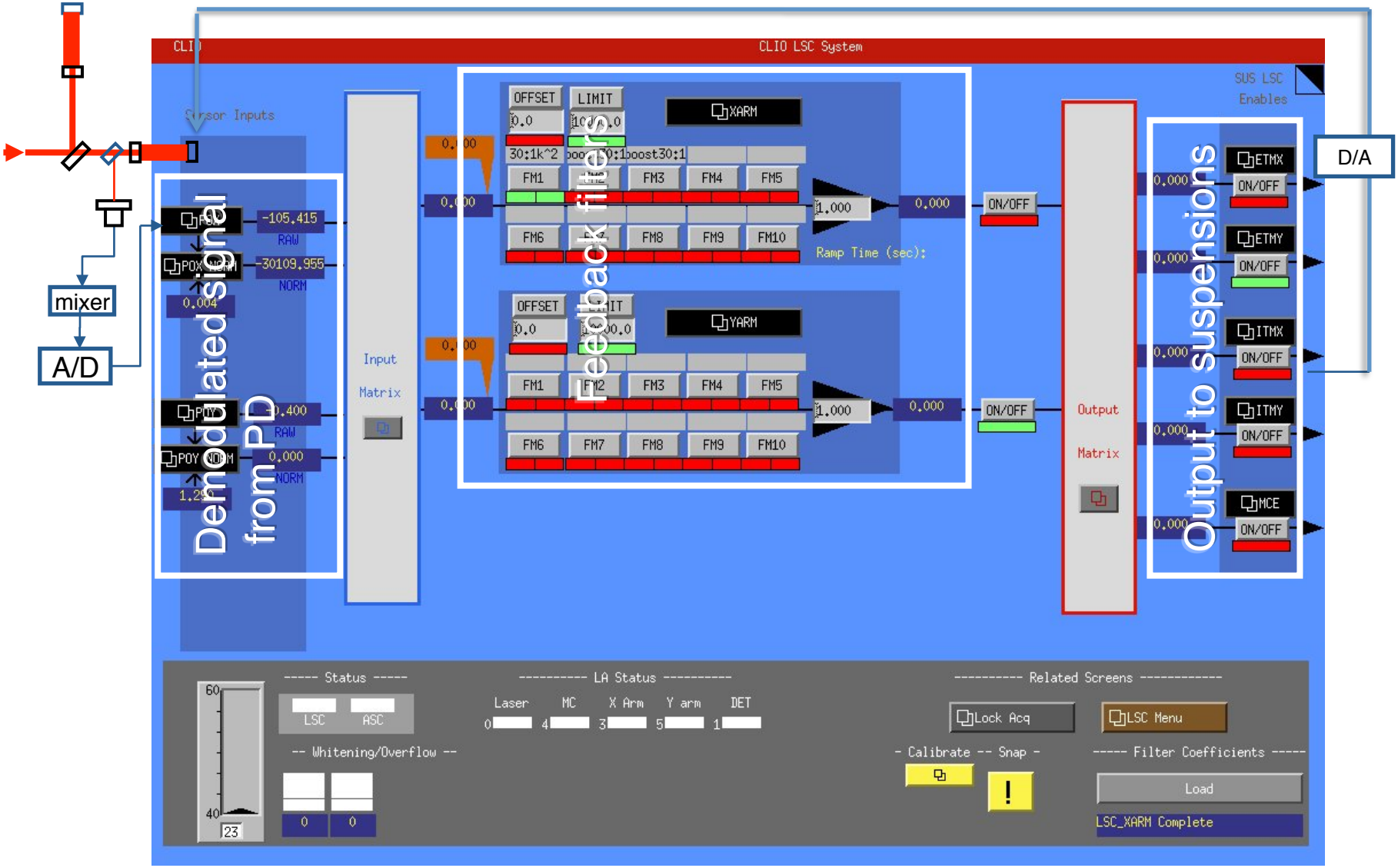
# Hardware and software

1. Dual x86 processors, with four CPU cores each.
2. Processor clock speed of 3GHz.
3. Eight (8) Gigabyte of memory.
4. Two Gigabit Ethernet interfaces.
5. One, or more, real-time network interfaces
   - Reflected Memory (RFM)
   - PCI Express (PCIe) network interface
6. A PCIe interface to the PCIe expansion chassis with a maximum of 14 PCIe cards installed.

# Real time code on Matlab, Simulink

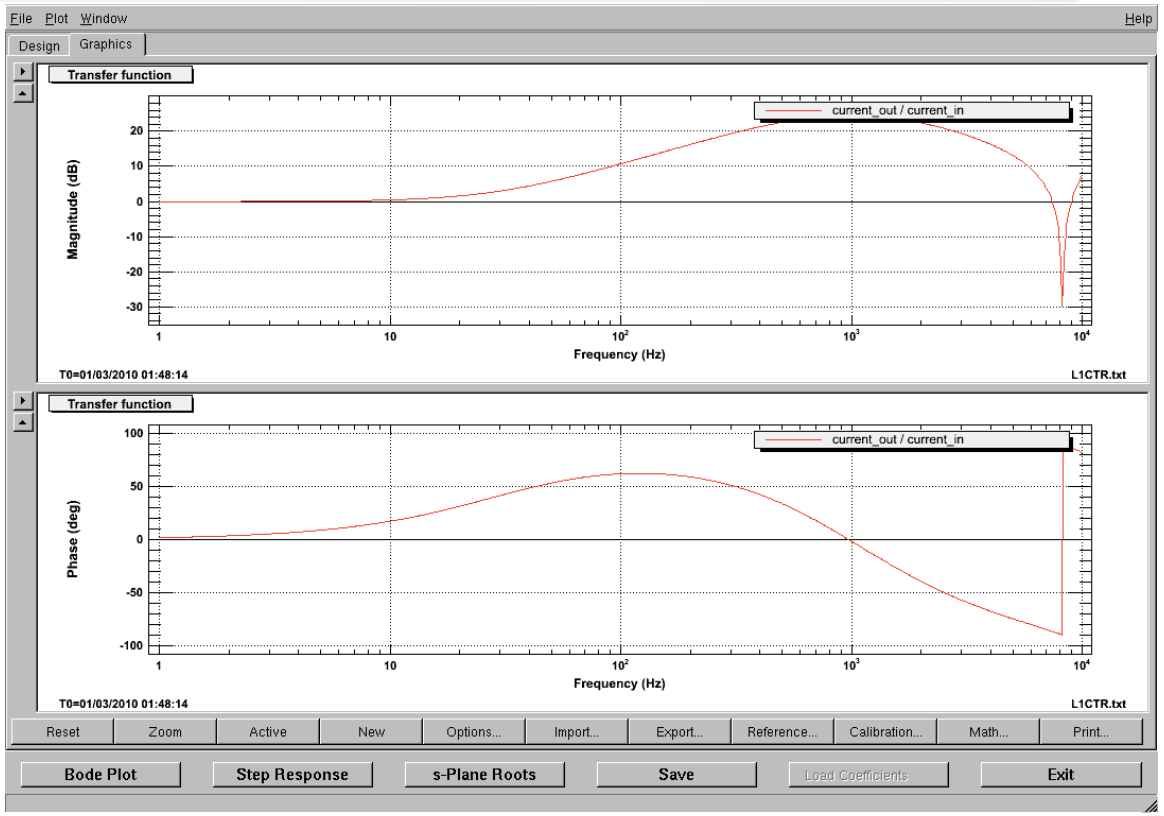


# MEDM --Length sensing and control system



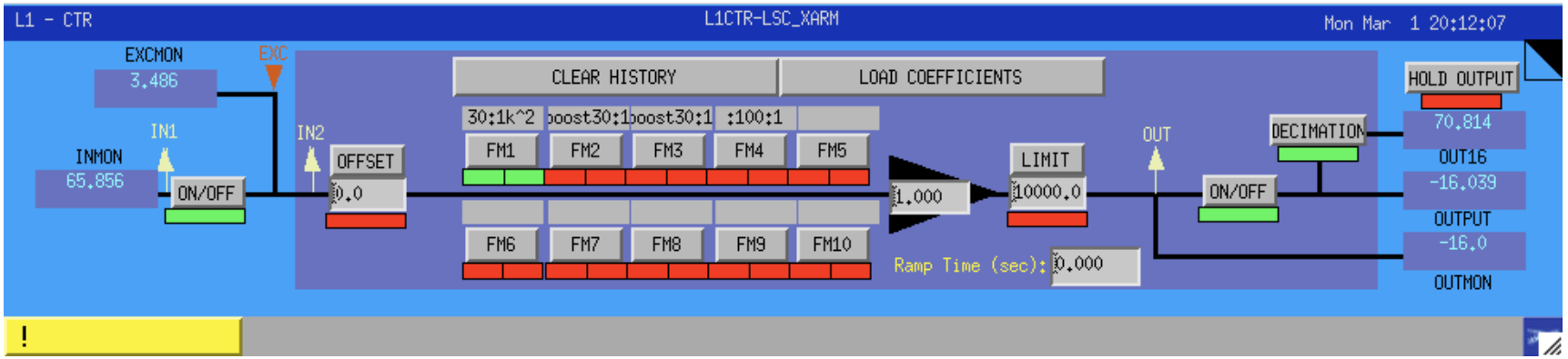
# Monitor/diagnosis software

- Dataviewer: osciloscope,
- DTT: FFT analyzer
- Foton: digital filter composer
- Ezcademod: digital modulator/ demodulator
- Foton: GUI digital filter composer

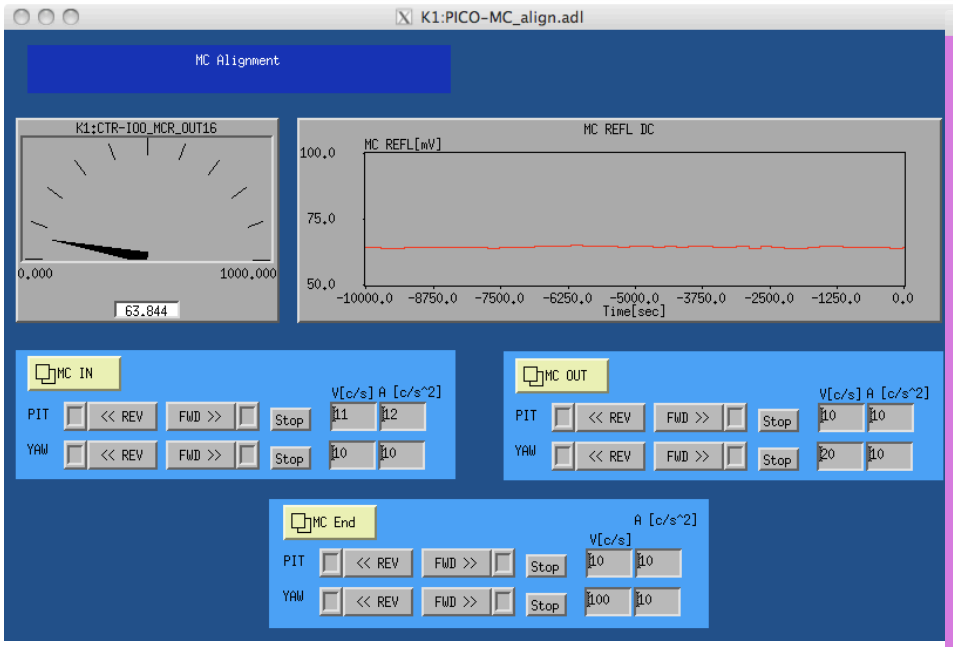


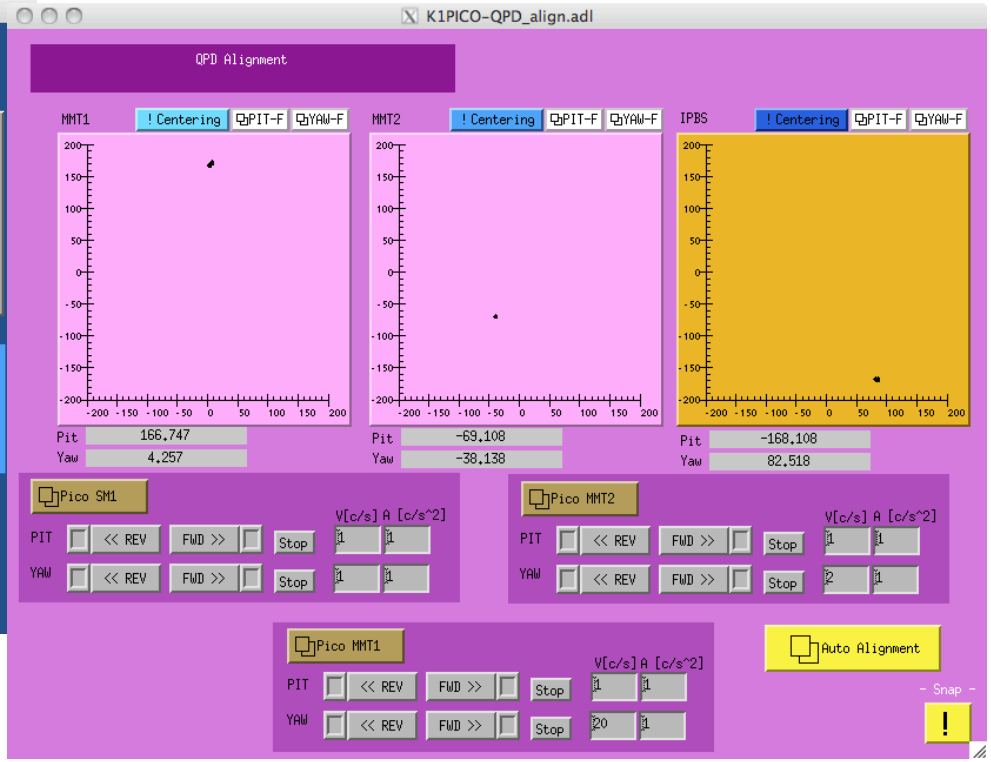

Filters on MEDM

- Signal excitation
- 10 filter banks
- 3 monitor point IN1/IN2/OUT



# QPDを利用した自動入射ビームアラインメント

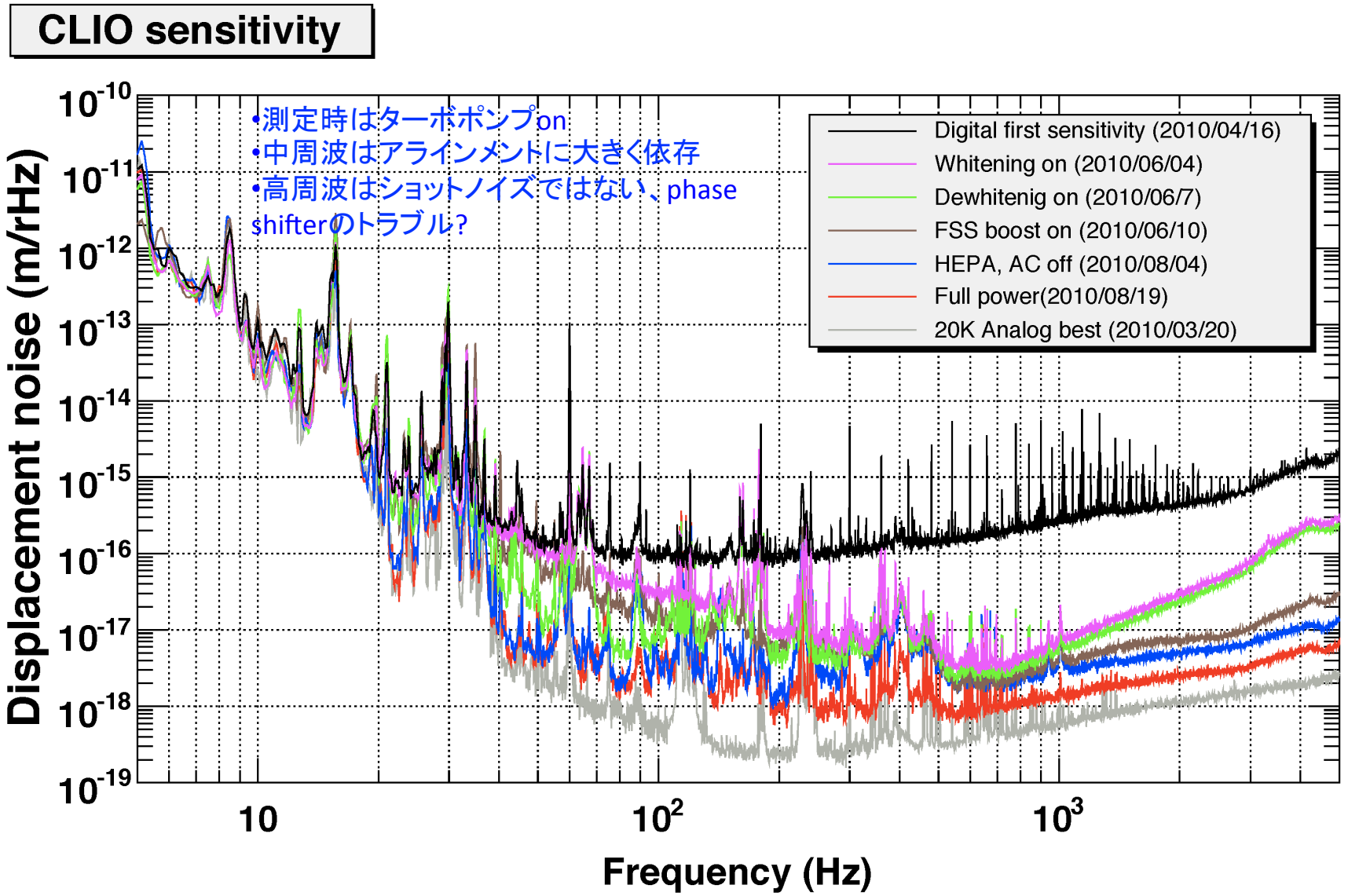


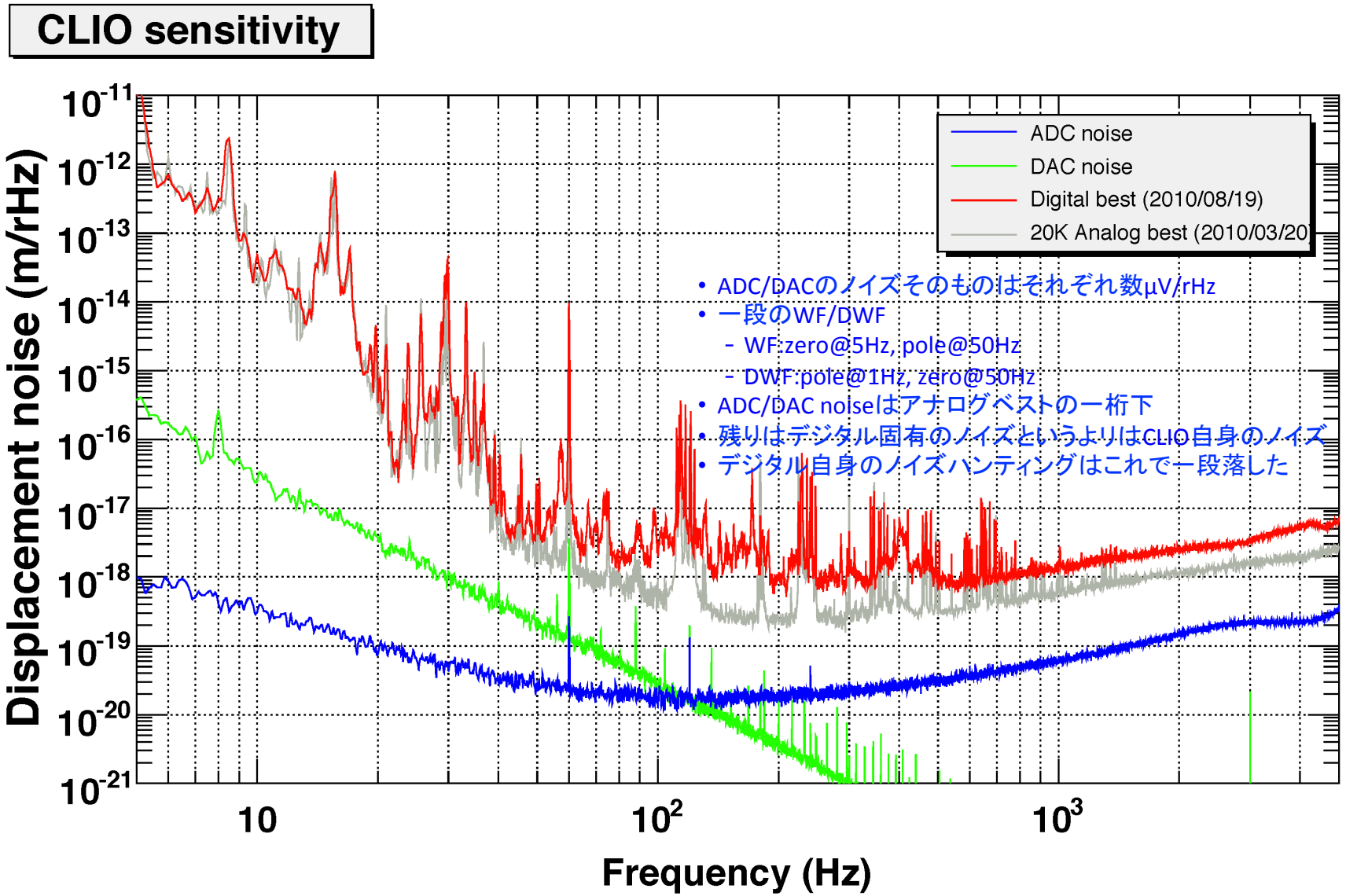

```
##MMT1 QPD centering
#pitch
python /cvs/cds/kami/scripts/AutoAlignment/DitherAlignment.py --freq 5 --excGain 0 --fbGain 0.1 --readBackChan
"K1:CTR-AIS_MMT1_PIT_OUT16" --feedBackChan "K1:PICO-SM1_PIT" --successCond 10 --fbWait 1 --timeout 120

#yaw
python /cvs/cds/kami/scripts/AutoAlignment/DitherAlignment.py --freq 5 --excGain 0 --fbGain 0.005 --readBack
Chan "K1:CTR-AIS_MMT1_YAW_OUT16" --feedBackChan "K1:PICO-SM1_YAW" --successCond 40 --fbWait 1 --timeout 60
```

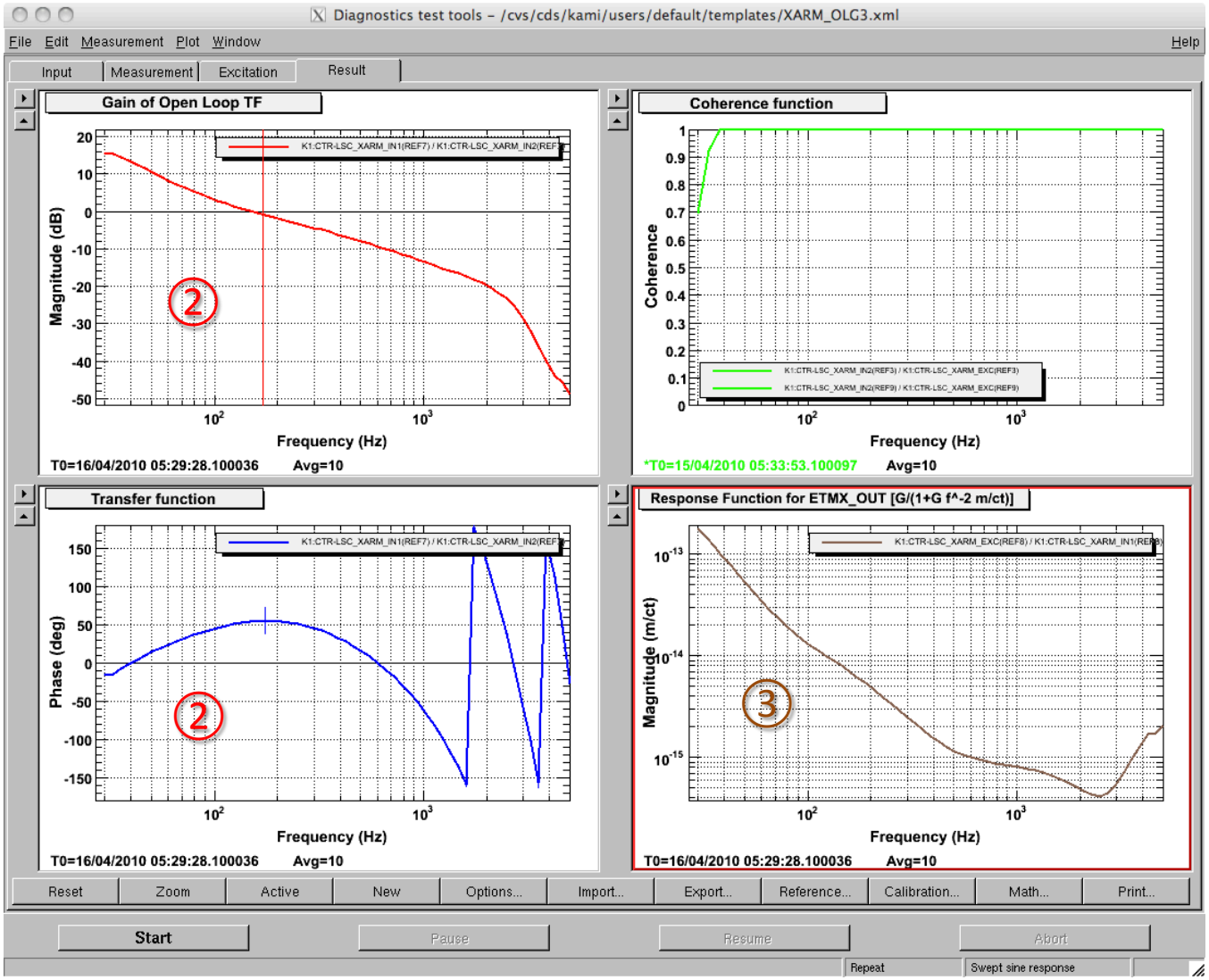
# Digital制御での現CLIO感度



# AD/DAC noise


CLIO sensitivity
Displacement noise (m/rHz)
Frequency (Hz)
ADC noise
DAC noise
Digital best (2010/08/19)
20K Analog best (2010/03/20
• ADC/DACのノイズそのものはそれぞれ数μV/rHz
• 一段のWF/DWF
– WF:zero@5Hz, pole@50Hz
– DWF:pole@1Hz, zero@50Hz
• ADC/DAC noiseはアナログベストの一桁下
• 残りはデジタル固有のノイズというよりはCLIO自身のノイズ
• デジタル自身のノイズハンティングはこれで一段落した
*T0=08/09/2010 01:16:38
*Avg=17/Bin=4L
*BW=0.187493

# Calibration




1. ロック中、サスペンションアクチュエータ直前のノイズ①をデジタル内で測定

2. Open loot TF:Gを測定②

3. ②を(1+G)/G*f^-2*m/ctに変換③

4. Calibrated noise: ① * ③（前ページの図）

5: 次回以降Calibrateしたいときはは UGFを常に同じになるように制御ゲインを調整すればよい

→ 常時感度モニタの実現

- UGFより低い周波数ではフィルターの形を任意に変えてもOK（高い周波数を変えたらOLTFの再測定）
- ノイズ測定ポイント以前ではゲインを変えても構わない（測定点以降のゲイン変化は補正が必要）

# Connecting subsystems into digital system

Front-end PC
- Real time core

Network router

Workstation
- Dataviewer(oscilloscope)
- DTT(FFT)
- Foton(digital filter setting)

IO chassis

ADC DAC BO

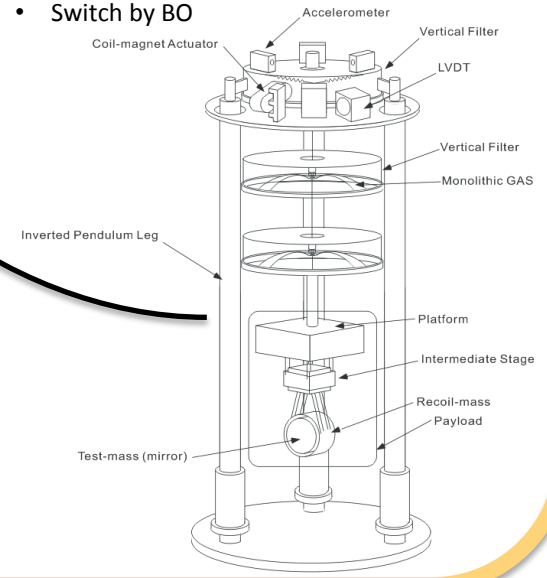
Prepared by each subgroup

Interface/driver box
- Variable gain stage
- Whitening
- dewhitening filter
- Switch by BO

Anti Alias filter box

Anti Imaging filter box

Binary Output interface box



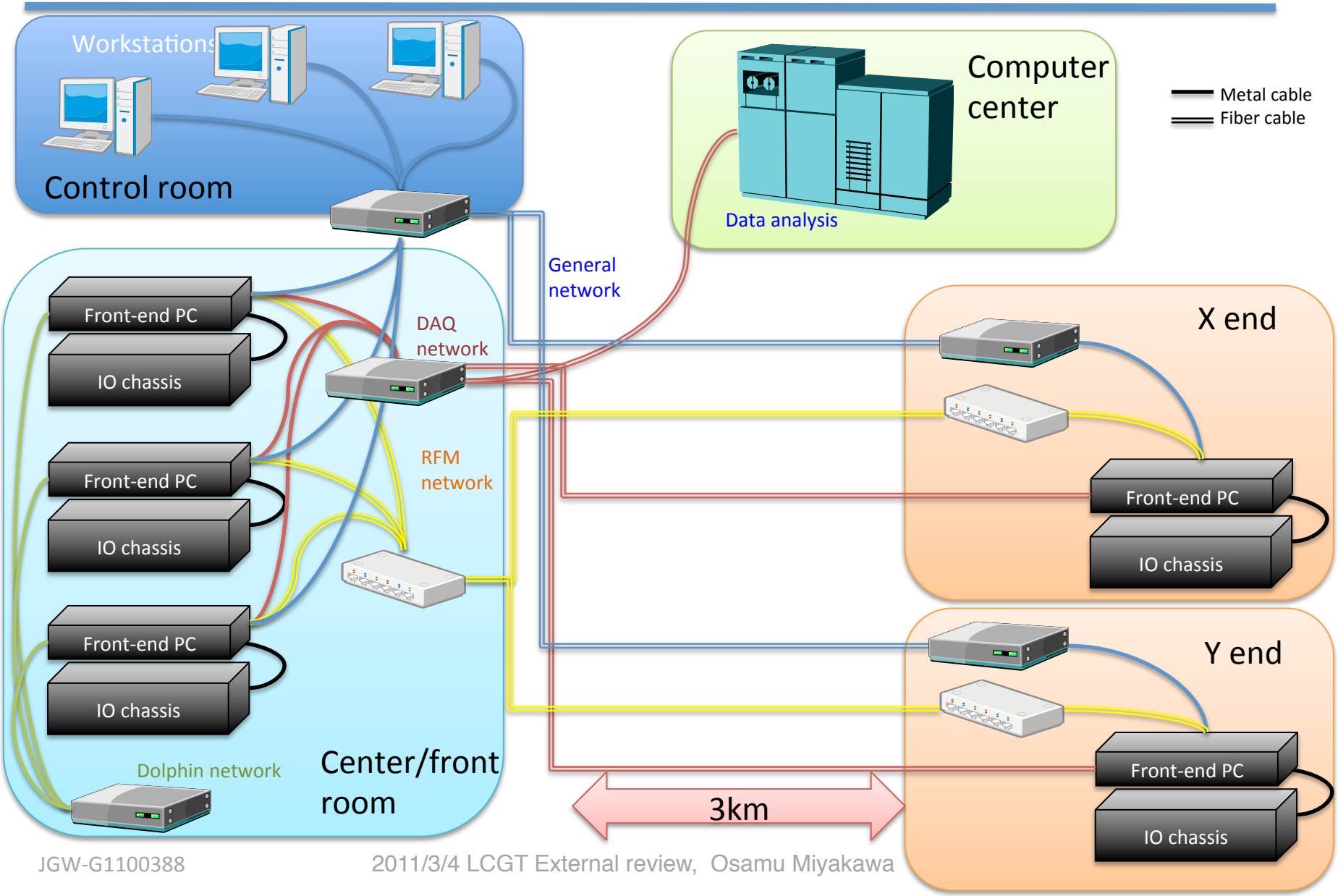

:D-sub connector

# Interface

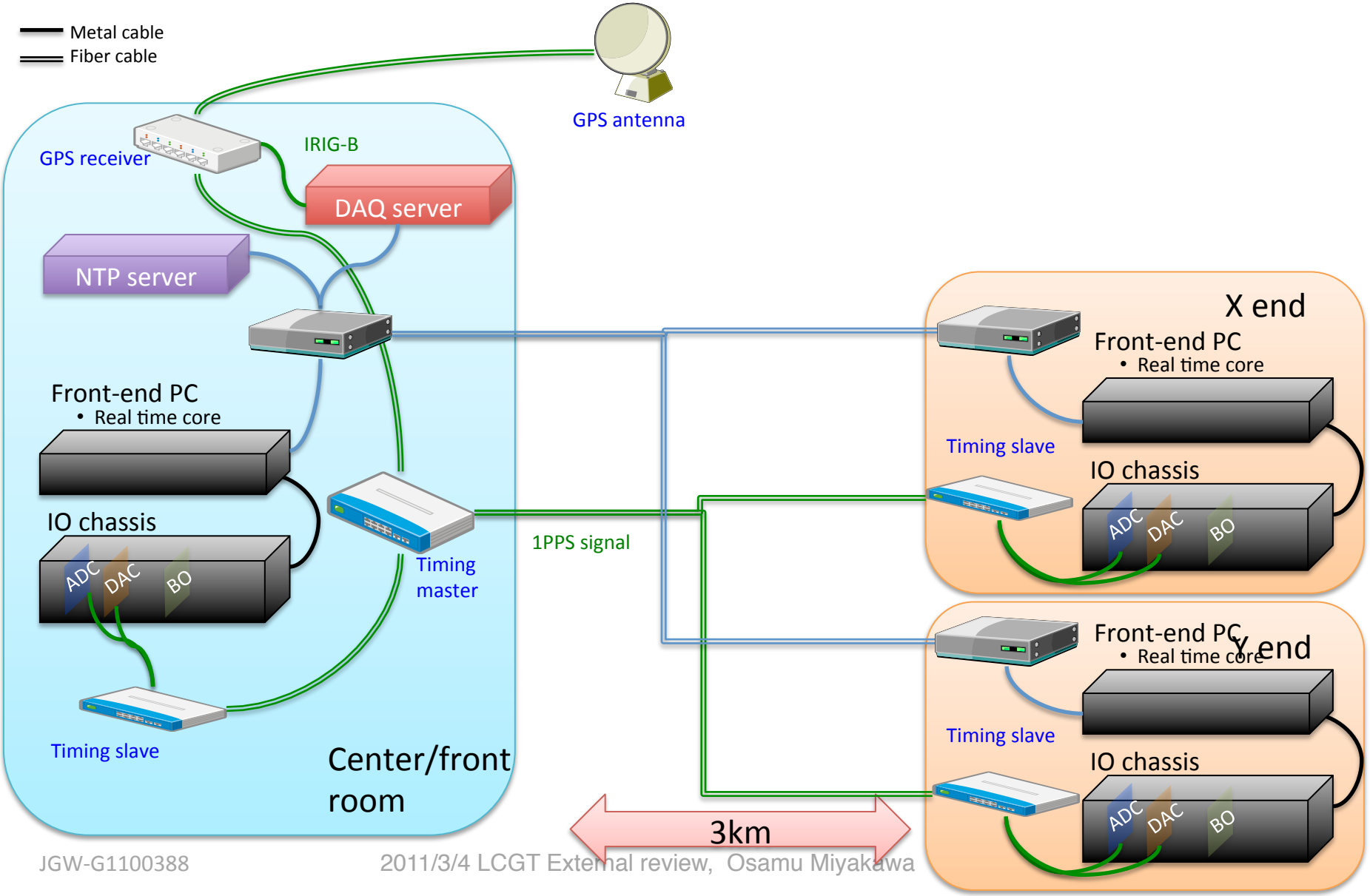
- ADC 32ch/card
  - 16kHz sampling
  - With Anti Alias filters
  - 2uV/rHz
  - D-sub 9pin(for 4ch, differential), +/-20V input
- DAC 16ch/card
  - With Anti Imaging filers
  - 1.5uV/rHz
  - D-sub 9pin(for 4ch, differential), +/-10V output
- BO 32ch/card
  - D-sub 9pin(for 4ch, differential), 0 or +5V output
    - Ex. Variable gain amp for 16 steps/1 D-sub connector

Note: D-sub 37pin may be supported for all input/output

# Network design



# Timing Network



# Making channel lists

- Needs channel list for ADC/DAC/BO
  - ADC input ~2048ch
    - will be categorized as class1(IFO main), class2(IFO sub), class3(PEM, physical environment monitor)…
  - DAC output: ~512ch
  - BO: ~2048ch
- DAQ channel: stored signals to data storage as 16kHz, 2kHz, 64Hz…

# DAQ Channel list

| | | | |
|---|---|---|---|
| | Number of stored channels | Data acquisition, Data analysis, IFO control | 16kHz:64ch, 2kHz:512ch, 64Hz:1024ch<br>16Hz:16384 epics channels<br>(see channel list) |
| * | Data bit resolution at ADC/DAC | Data acquisition | 16bit = 65536 |
| * | Data bit resolution in PC | Data acquisition | 32bit = 4 Byte integer |
| | Data transfer rate | Data acquisition | 4MB/sec for 16kHz,<br>4MB/sec for 2kHz,<br>128kB/sec for 64Hz,<br>1MB/sec for 16Hz,<br>Total ~10MB/sec<br>~30GB/hour<br>~1TB/day<br>~300TB/year |

## 6. Channel list

a. 16kHz (total 64ch)

| Part | Channel point | Channel number | Description |
|---|---|---|---|
| Laser | Output laser power[W] | 1 | |
| | IFO Input laser power[W] | 1 | |
| MC | REFL | 1 | |
| | MC length feedback | 1 | |
| | MC frequency feedback | 1 | |
| | | | |
| LSC | I&Q dor DARM, CARM, MICH, PRC, SRC, etc. | 10 | |
| | error, feedback | 10 | |
| SUS | length * 10 suspensions | 10 | |
| | | | |

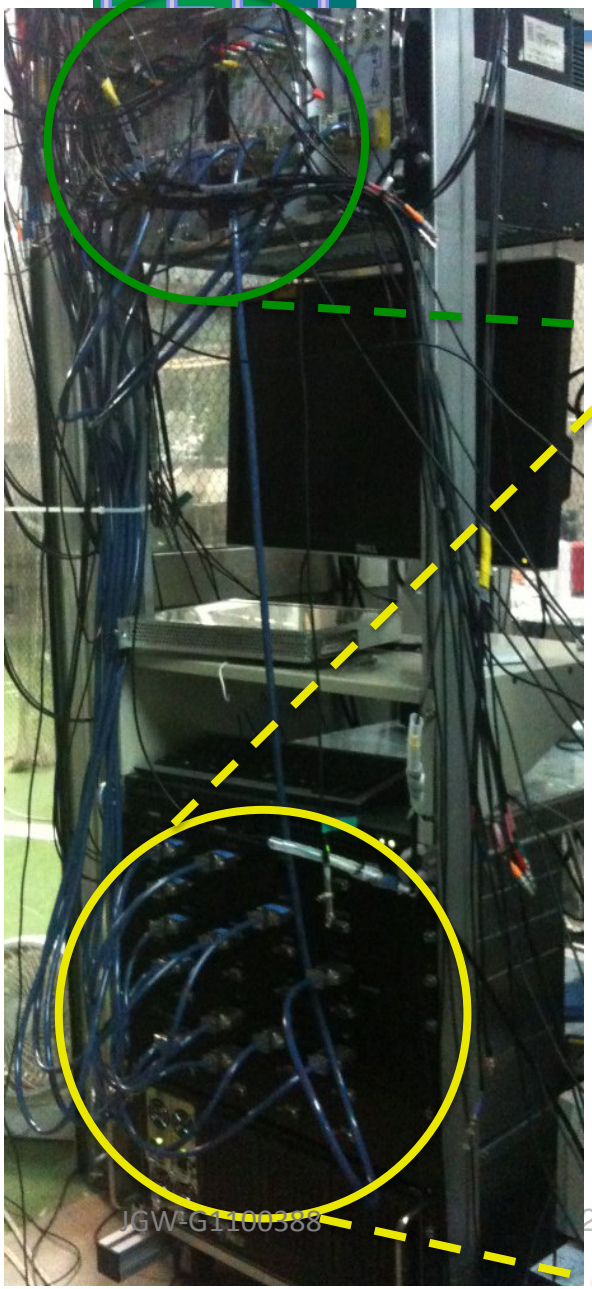
b. 2kHz (total 256ch)

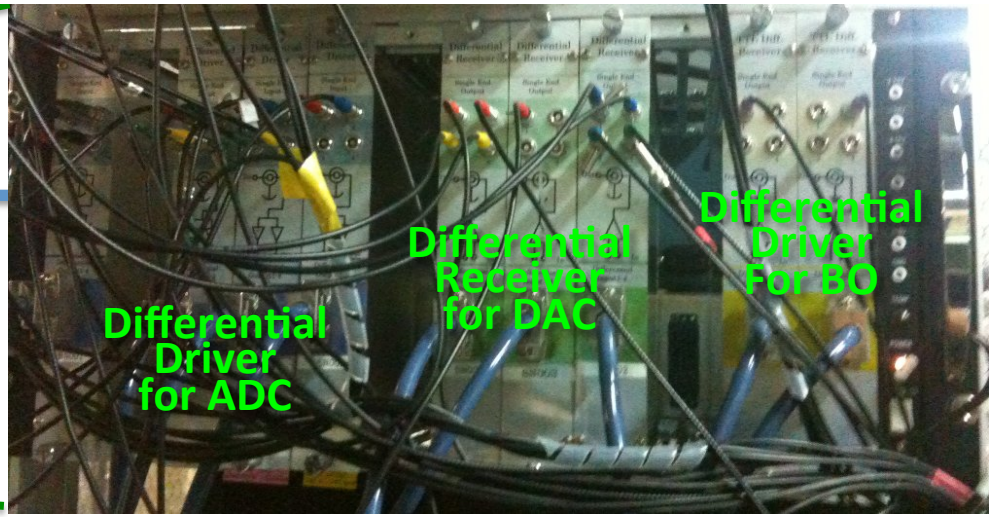
| Part | Channel point | Channel number | Description |
|---|---|---|---|
| ASC | WFS | 5xpitch, yaw=50 | |
| | Oplev | 10xpitch,yaw=100 | |
| | | | |

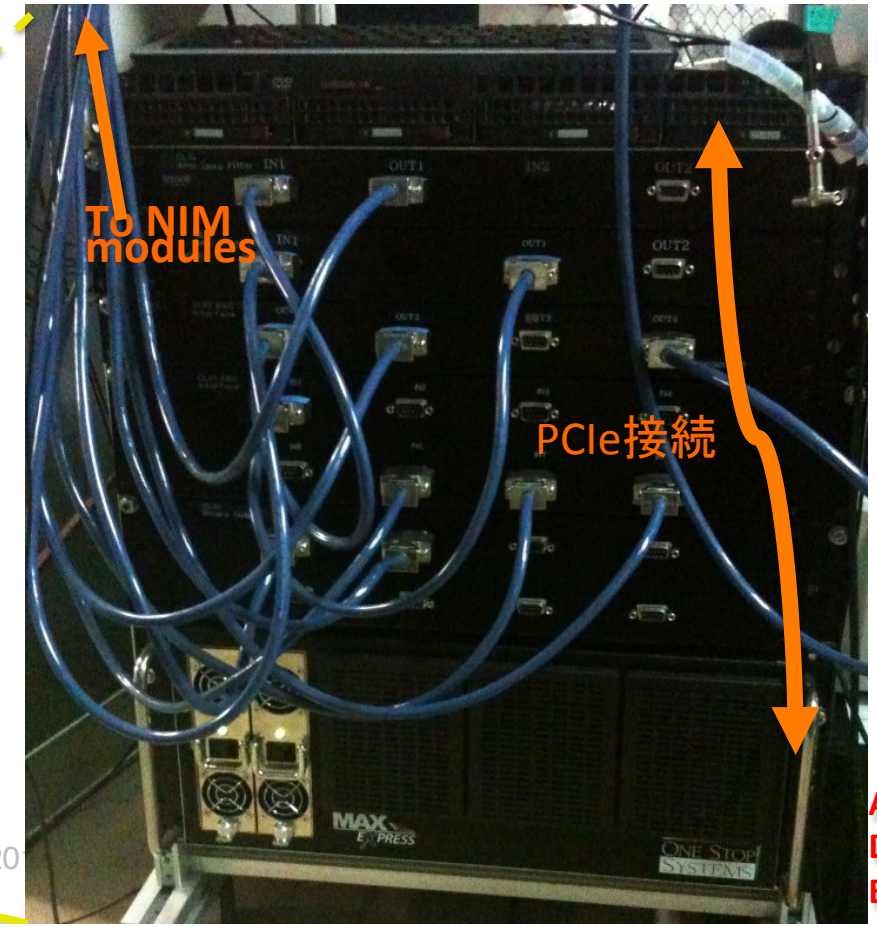
c. 64Hz Long term monitor (total 512ch)

| Part | Channel point | Channel number | Description |
|---|---|---|---|
| Temperature[deg] | room | 10 | center, end, arm |
| | table | 10 | laser, REFL, AS, pickoff, end |
| | suspensions | 50 | Low temperature |
| | mirrors | 50 | Low temperature |
| Humidity[%] | rooms | 10 | center, end, arm |
| Dust | rooms | 10 | center, end, arm |
| Laser | crystal temperature[degree] and etc. | 10 | |
| | Master laser power[W] | 2 | |

# Pictures






**Real time PC**
CentOS 5.2+real time kernel
4core x 2 Xeon

**Anti Imaging filters**
**Anti Alias filters**

**DAC adapter**

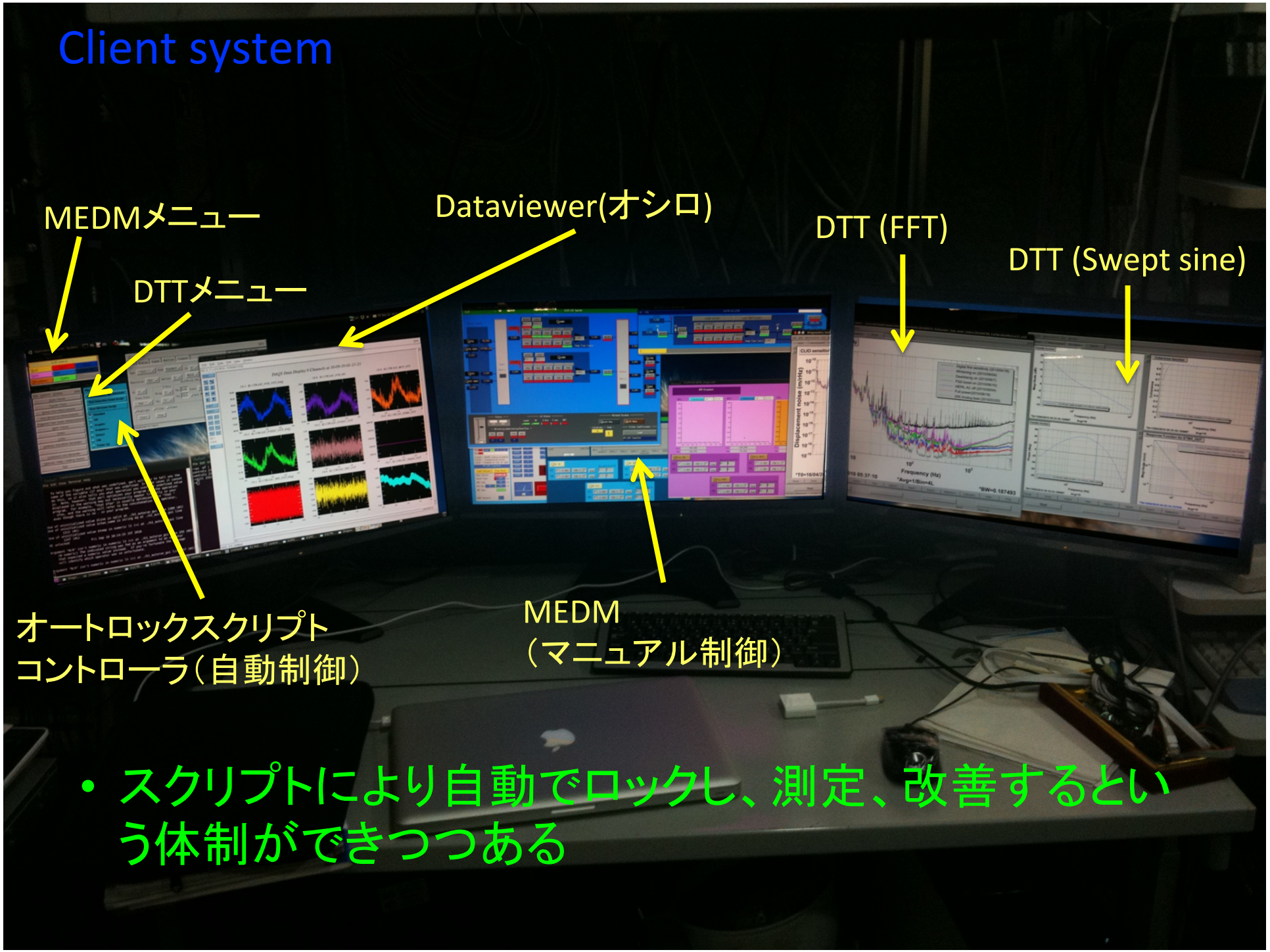
**ADC adapter**

**Binary output adapter**

**ADC/DAC**
**In Expansion Chassis**

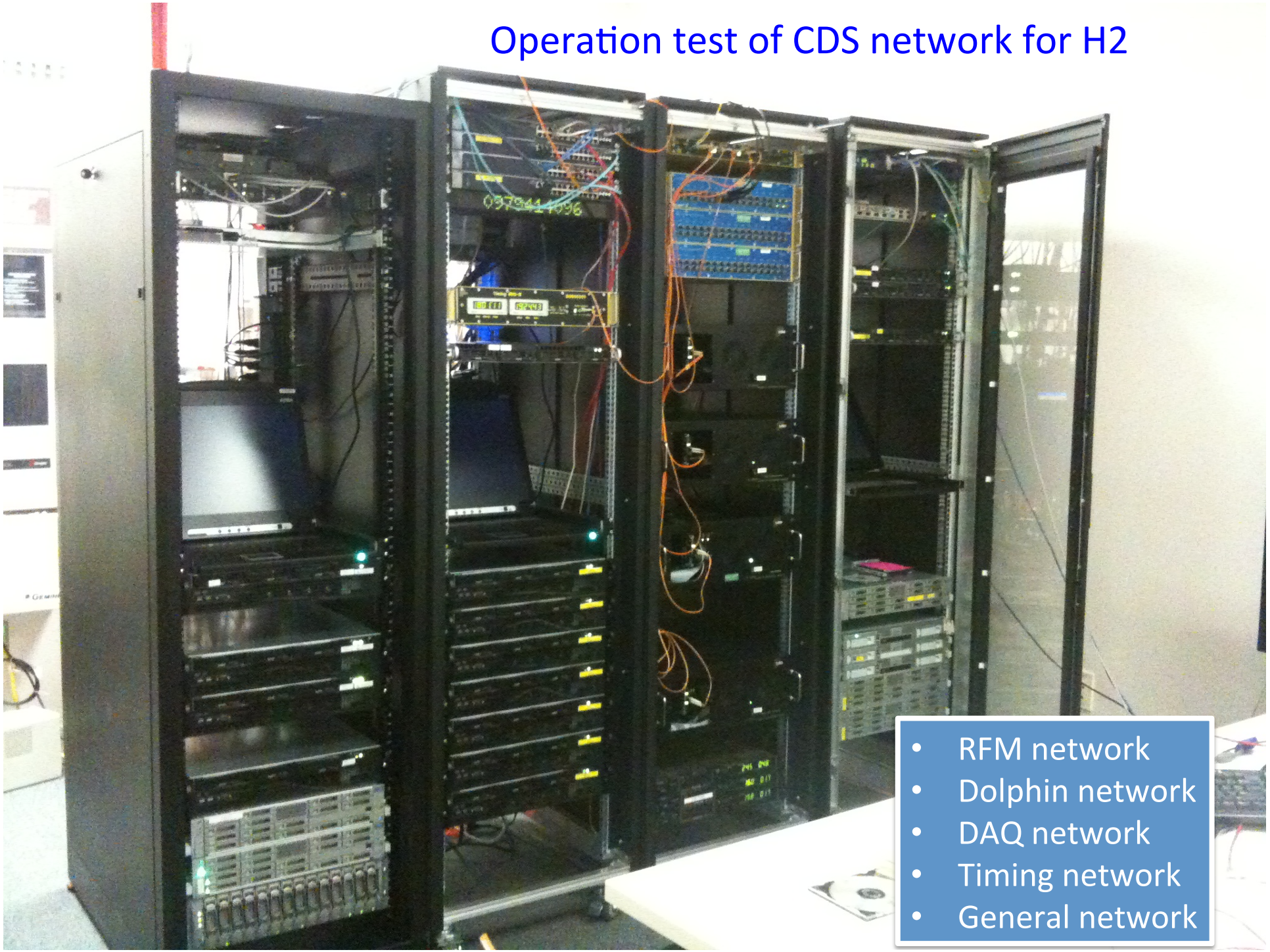
ADC:32ch/$4K
DAC:16ch/$3.5K
Binary Output:32ch/$250

# Client system




- スクリプトにより自動でロックし、測定、改善するという体制ができつつある

# Operation test of CDS network for H2



- RFM network
- Dolphin network
- DAQ network
- Timing network
- General network