



Real-Time Processing the MSE data with GPGPU in KSTAR

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14th May, 2019

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Overview the KSTAR control system



❖ Control system features

- The KSTAR Control System has been developed using **EPICS** (Experimental Physics and Industrial Control System) as a middleware of control and DAQ system
- From 2008, The KSTAR has **various form factor DAQ** systems for measuring the various plasma properties. : VME, cPCI, PXI, VXI and etc.
- Using two types of database :
 - ✓ **EPICS Channel Archiver** : continuously produced machine operational data at a low rate
 - ✓ **MDSplus** : shot-based experimental pulse data with a large volume
- Development & Operating software : EPICS, MDSplus, Qt, Linux, Vxworks, Windows, CCS, etc

❖ Requirements and Technical issues :

- Raises maintenance and development issue the various form factor DAQ systems (H/W & S/W)
- Use as real-time control without interfering with data archiving
- Malfunction due to the Ageing of equipment

❖ Adopt the **MTCA.4** for standardization of a fast controller (DAQ) :

- Developed the **KSTAR Multi-function Control Unit (KMCU)** at '15 ~ '16 : ver KMCU-Z35 (For High performance)
- Developed new version of KMCU for suitable device at '16 ~ '17 : ver KMCU-Z30 (It has 2 SFP+ port in front panel.)
 - ✓ Advantages of this device are simultaneous two (or three) point streaming data transmission for plasma control or acquisition system.
 - ✓ And standalone operation capability for a small size diagnostics

Assembled KMCU Z30, Z35 and uRTM

□ Appearance of manufactured MTCA.4 modules

- KSTAR Multi-function Control Unit : KMCU-Z30



MicroTCA rear transition module (ACQ400-MTCA-RTM2):

- Carrier board for various input/output module.
- Two mountable sites supports elongated FMC



KMCU Z35

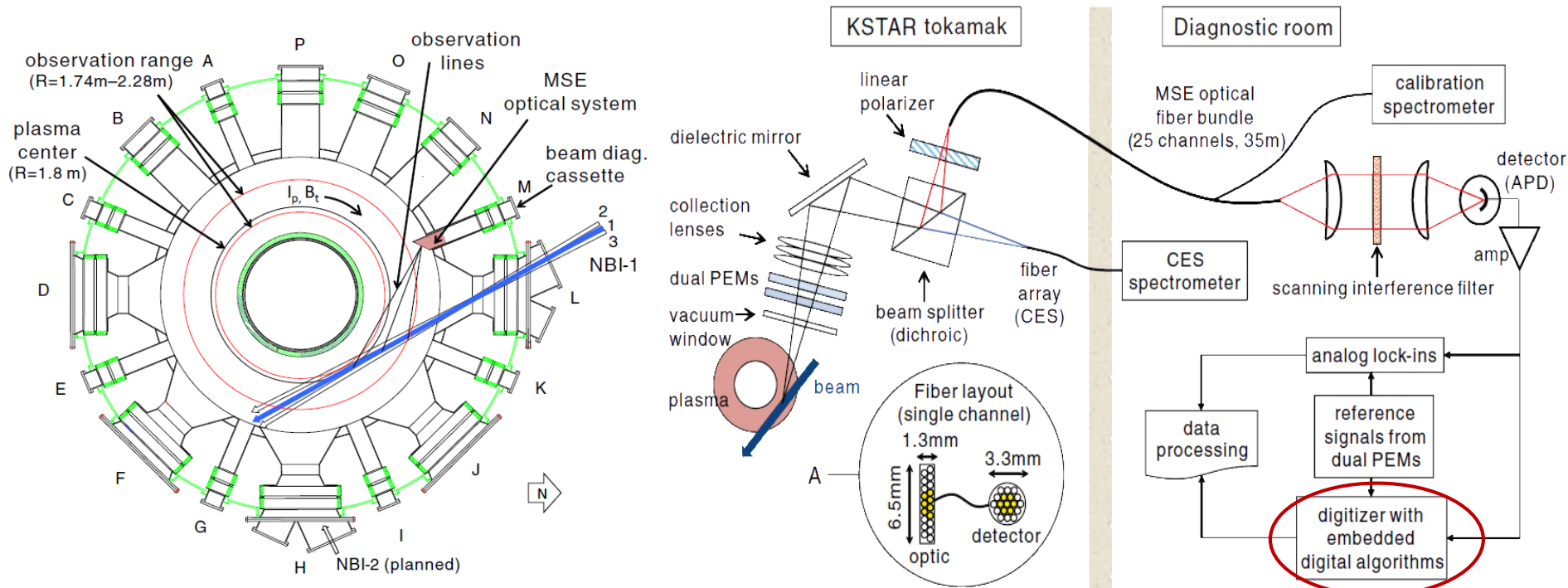


KMCU Z30

KSTAR MSE diagnostic system

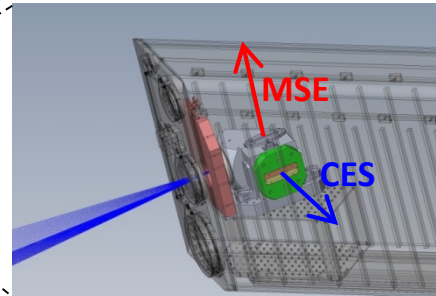
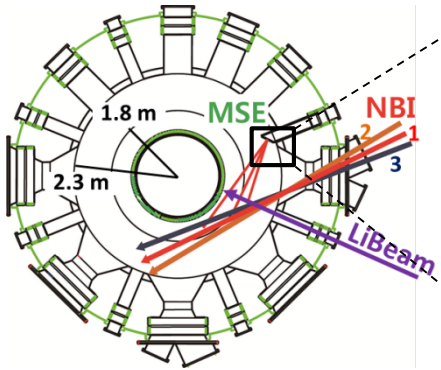
□ A multichord photo-elastic modulator based MSE system

- The MSE (motional Stark effect) diagnostic is used to measure the radial magnetic pitch angle profile in neutral beam heated plasma.
- Top view of the KSTAR tokamak showing locations of a set of neutral beam from the NBI-1 on port L and observation lines of MSE diagnostic in the beam diagnostic cassette on port M.
- The KSTAR doing parallel works of analog lock-in and digital lock-in (real-time data processing) – You can see about analog lock-in in poster section on Thursday. (P/4-2) (Thursday 16 May).
- A digital lock-in technique will help real-time q-shaping control to optimize the confinement and the stability.



Courtesy J. Chung

KSTAR MSE diagnostic system



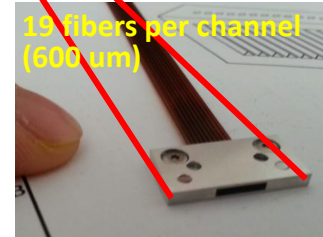
Front optics inside cassette (2014-2015)



Fiber holder/dissector (2014-2015)



Filter/APD modules (2015)



19 fibers per channel (600 um)



In-vessel calibration (May 2015)

- 25 channels, $\Delta r/a \sim 2 - 8 \%$ (similar to that of ITER)
- $\Delta t \sim 10$ msec ($\tau_E \sim 0.1$ sec, $\tau_{CR} \sim 1$ sec at KSTAR)
- Photoelastic modulator (PEM) polarimeter with the FFT algorithm to extract the polarization angle
- Elaborate calibration/analysis procedures optimized
- Underway: MDSPlus / MSE-EFIT interface / Direct q & J profiles

Ko (FED, In press), Chung (RSI,2014, JKPS2014), Ko (JKPS2014)

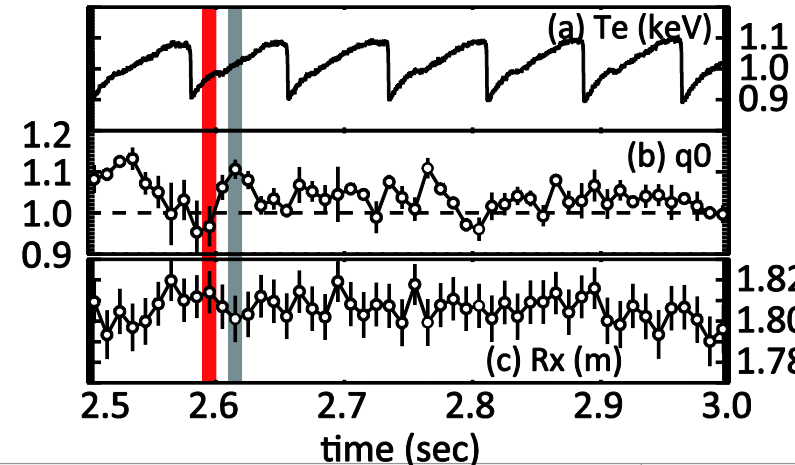
Example from 13502, $\Delta t = 10$ msec
(not absolutely calibrated) but...

$$1.13 \pm 0.023 \text{ (2.615 sec)}$$

$$0.99 \pm 0.049 \text{ (2.595 sec)}$$

This is an actual construction photograph of MSE and is an application example of physics research.

thu 25 feb 2016, j ko, kstar conference



MSE DAQ Systems configuration and interface

□ MSE-GPGPU (for data processing) & MSE-K (for data saving)

- MSE-MIT DAQ system (96ch) – using PCIe-uplink for three KMCU-Z30
- Duplicated streaming data transmission for MSE-K & GPGPU – 32ch (using SFP+ x 2)

BNCPANEL 32ch x 3

KMCU-Z30 (x 3): for MSE-MIT

- x1 : using PCIe uplink
- Use front panel Ethernet
- ACQ400-MTCA-RTM2 – 1 : RTM with 2 x ELF sites
- FMC-424ELF x6 : 16bit 2MSPS, 16ch x 6 : 96ch

PCIe uplink (MPCIE4-T2) :

- PCIe x4 Gen2 optical link composed of AI-9194 (quad fiber optical)

MCH (NAT-MCH-202201)

12-slot MTCA.4 crate with P/S

Host controller (MSE-MIT):

- 16GB RAM, 256GB SDD x 2
- NVMe M.2 970Pro x1 : 1TByte
- AI-9194 (PCIe x4, Gen2)

BNCPANEL x1

LTU (Time Sync system)

- Resolution : 5 ns

KMCU-Z30 (x 1): for MSE-K

- SFP+ x 2 : to MSE and GPGPU
- Use front panel Ethernet

Data link to Host PCs:

- 2 x SFP (2 x SFP)
- Duplicated streaming data transmission
- MSE-K & MSE-K-GPGPU

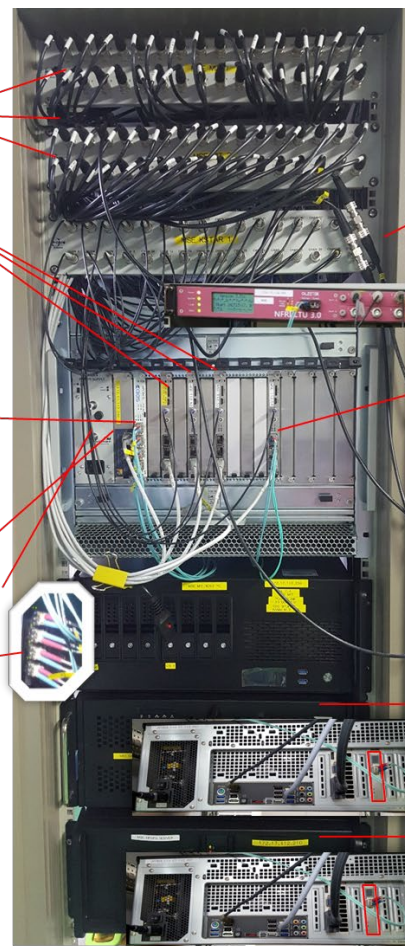
MSE-K : To Data Saving

- 16GB RAM, 256GB SDD x 2
- AFHBA400 x 1 (PCIe x1 HBA, 1 x SFP 2.5Gbps)

MSE-K GPGPU : To Data Processing on Real-Time

- 16GB RAM, 256GB SDD x 2
- AFHBA400 x 1 (PCIe x1 HBA, 1 x SFP 2.5Gbps)
- GPGPU : GeForce GTX 1070

- Scientific Linux 7.2 (3.10.0-327 64bit)
- EPICS R3.14.12.2



❑ To real-time control with MSE data

- Requirements to real-time data processing in MSE-GPGPU system
 - ✓ Data processing loop time : ~ 8msec (<8.2msec) .
 - ✓ To FFT data signal : need at least 5msec of data (depends on signal quality and data rate)
- The MSE DAQ system streaming data (1MByte) update rate : about 128 Hz (with 32ch, 2MSPS, 16bit)
- Simple check the 1MB data processing time :
 - ✓ 1MB (8.2msec data- 2MSPS) data read time from RAM disk in CPU: ~ 1.2msec
 - ✓ Memory Copy - Host to CUDA device : ~ 0.8msec
- The data must be processed within 5.4 msec on the GPU. : < 5.4msec (8.2 - 2.8)
- The MSE-GPGPU system don't save raw data.

❑ Summary and Future Work :

- We are ready to develop the real-time data processing for digital lock-in without dependence the MSE diagnostic data archiving missions.
- We confirmed the possibility of real-time data processing with GPGPU.
- The real-time control of the current profile is a long-term challenge.
- In this campaign, I will test the MSE data processing by applying FFT function.
- Then I will incrementally add computational logic to make meaningful data.