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Real-Time Processing the MSE data with GPGPU in KSTAR

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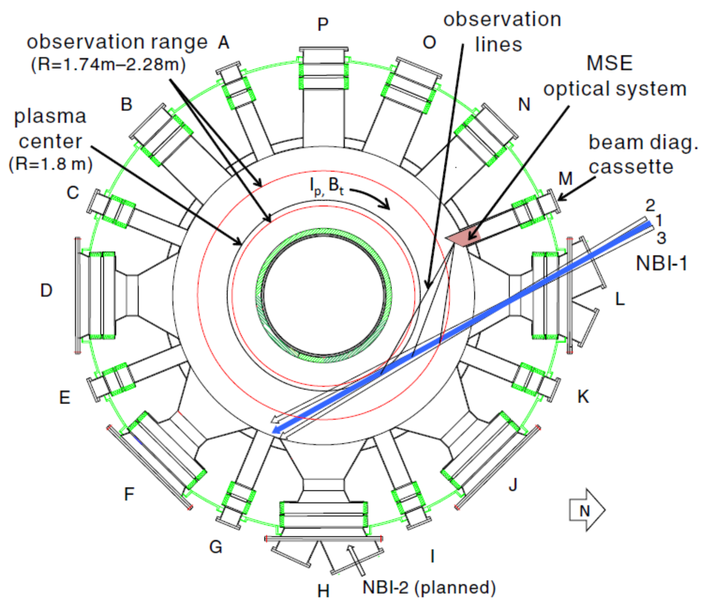
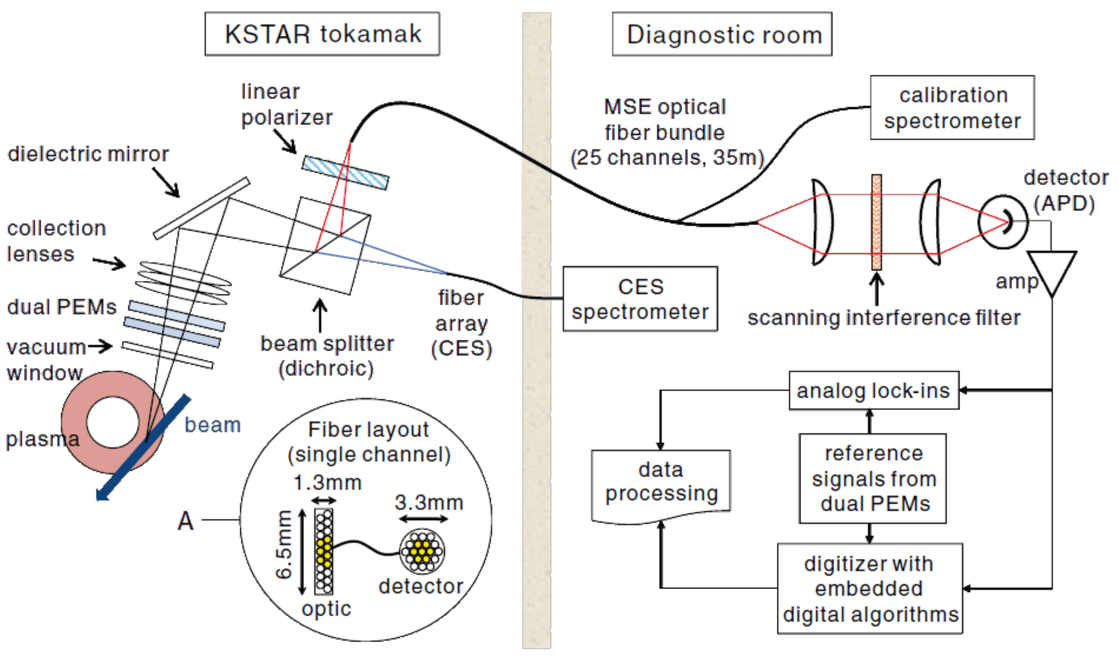
The KSTAR has MSE (Motional Stark Effect) diagnostics devices for measurement of plasma current density distribution. Real-time MSE is an essential diagnostic for advanced control over the *q*-profile in tokamaks [1]. The KSTAR MSE diagnostic data measurement system measures and stores a total of 25 signals and 2 reference signals at a rate of 2MHz sample per second. The KSTAR has developed the uTCA.4 form factor controller, KMCU-Z35 and KMCU-Z30, for KSTAR digitizer standardization, it has been used in some diagnostic data acquisition systems from 2016. The KMCU-Z30 can simultaneously transmit the same data in three directions from a single ADC digitizer (one PCIe and two SFP+), allowing device configurations to be configured individually for real-time control without interfering with raw data storing device system. In this campaign, we plan to apply the KMCU-Z30's data branching function and digital lock-in algorithm for real-time MSE which we plan to implement using GPGPU for fast data processing of high sampling data. This paper will describe the overall structure of the MSE DAQ system and performance of the real-time MSE data in KSTAR.

➢ Introduction

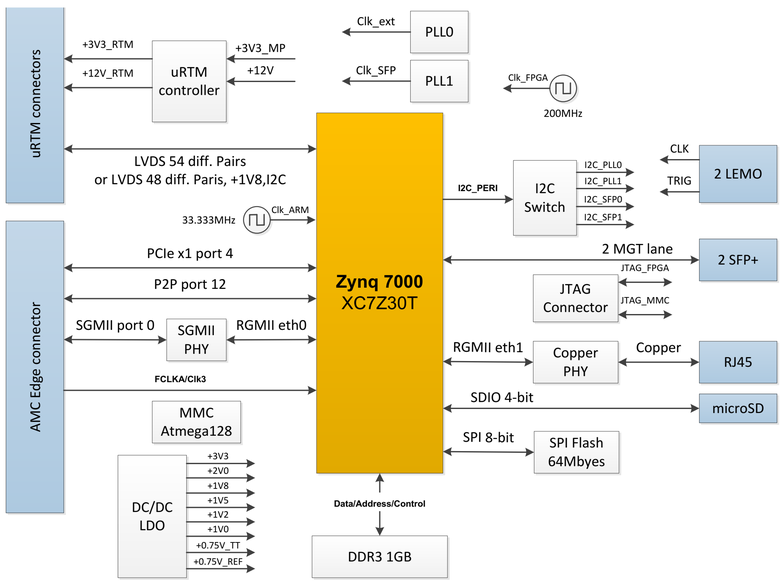
- To measure the radial magnetic pitch-angle profile in neutral-beam-heated plasmas.
- To save high sampling data in KSTAR DB (MDSplus)



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.

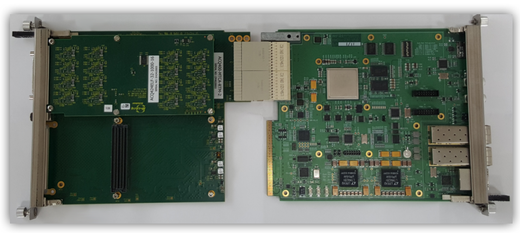


- Adopt the MTCA.4 for standardization of a fast controller (DAQ) [2,3] :
  - ✓ Developed the KSTAR Multi-function Control Unit at '15 ~'16 : ver KMCU-Z35 (High performance)
  - ✓ Developed new version of KMCU for suitable device at '16 ~ '17 : ver KMCU-Z30 (2 SFP+) [2]
  - ✓ Many diagnostic DAQ systems are using the KMCU-Z30 : MSE-MIT, MSE-K, etc
  - ✓ Duplicated streaming data transmission to different systems



ACQ400-MTCA-RTM2 – 2
- FMC-425ELF x 2

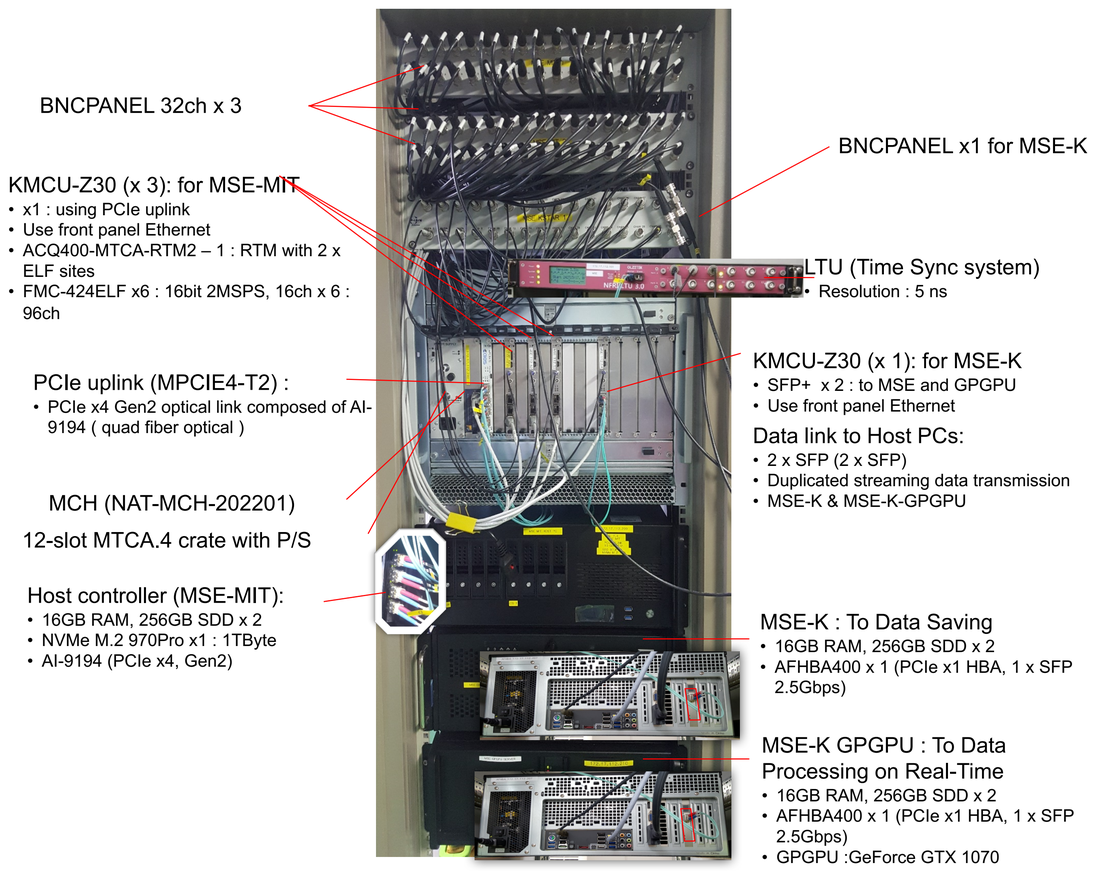
KMCU Z30



➢ Hardware configuration for MSE DAQ system

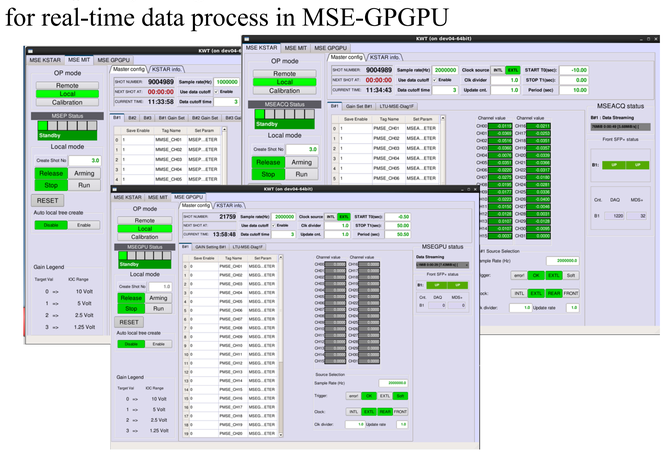
- Selection of the MicroTCA.4-form factor digitizer
- Chassis : 12-slot MTCA.4 crate with P/S
- Controller : KMCU-Z30 x 3 (for MSE-MIT : 96ch) & KMCU-Z30 x 1 (for MSE-KSTAR)
- PCIe uplink (MPCIE4-T2) : PCIe x 4 Gen2 optical link composed of AI-9194
- Digitizer : ACQ400-MRCA-RTM2-2 with FMC-425ELF x 2
  - ✓ ACQ400-MRCA-RTM2-2 x 4
  - ✓ FMC-425ELF x 8 : 16ch, ADC 16-bit @ 2MSPS, max +/-10V ~ 1.25V
- Time synchronization : LTU (Local Timing Unit) [4,5]
  - ✓ resolution and accuracy 5ns, output clock : 1Hz ~ 100MHz

- Host Controller x 3
  - ✓ MSE-KSTAR : KMCU-Z30 x 1 : 32ch, AFHBA, SSD x 2
  - ✓ MSE-MIT : KMCU-Z30 x 3 : 96ch – AI-9194 PCIe, NVMe M.2 970 Pro, SSD x2
  - ✓ MSE-GPGPU : Duplicated streaming data, AFHBA, SSD x1 GeForce GTX 1070



➢ S/W development for MSE DAQ systems

- Developed the KMCU IOC device/driver for control standardization DAQ with SFW & Simply create new EPICS IOC using script
- Edit the EPICS IOC to suit the purpose of the diagnostic DAQ system (number of channels, MDSplus node name for storing each channel data, etc.)
- Standard software framework(SFW [7]) composed of an EPICS library(sfwLib) & Provides essential functions to support common records
- Streaming data (1MB) archiving from KMCU-Z30 to host kernel buffer(1MB * 66)
- Extraction of 1 point data per each channel from 1MB data for raw and voltage data display on real-time
- After shot, DAQ system segment archives raw data from Local SSD to MDSplus DB (Central Storage)
- OPI panel has been developed by using in-house KWT [6]
- CUDA-8.0 Toolkit for real-time data process in MSE-GPGPU



➢ To real-time control with MSE data

- Requirements to real-time data processing in MSE-GPGPU system
  - ✓ Feed-back loop time : ~ 8.2msec.
  - ✓ To FFT need 5msec data (depends on signal and data rate)
- Streaming data (1MByte) update rate : about 128 Hz (with 32ch, 2MSPS)
- Check the 1MB data processing Time
  - ✓ 1MB data read time from RAM disk in CPU: ~ 1.2msec
  - ✓ Memory Copy - Host to CUDA device : ~ 0.8msec
- Don't save raw data in MSE-GPGPU server

➢ Summary and Future work

- The MSE (KSTAR & MIT) DAQ system successfully operate during KSTAR experimental campaigns with Micro TCA.4-form factor.
- A digital lock-in technique will help real-time q-shaping control to optimize the confinement and the stability.
- The real-time control of the current profile is a long-term challenge. We will gradually develop the real-time control system with GPU.

➢ References

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