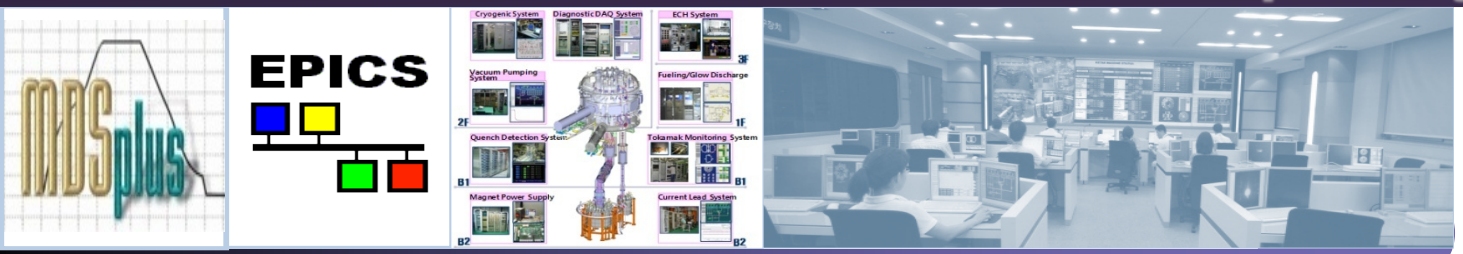

Design of GPU-based Parallel Computation Architecture of Thomson Scattering Diagnostic in KSTAR

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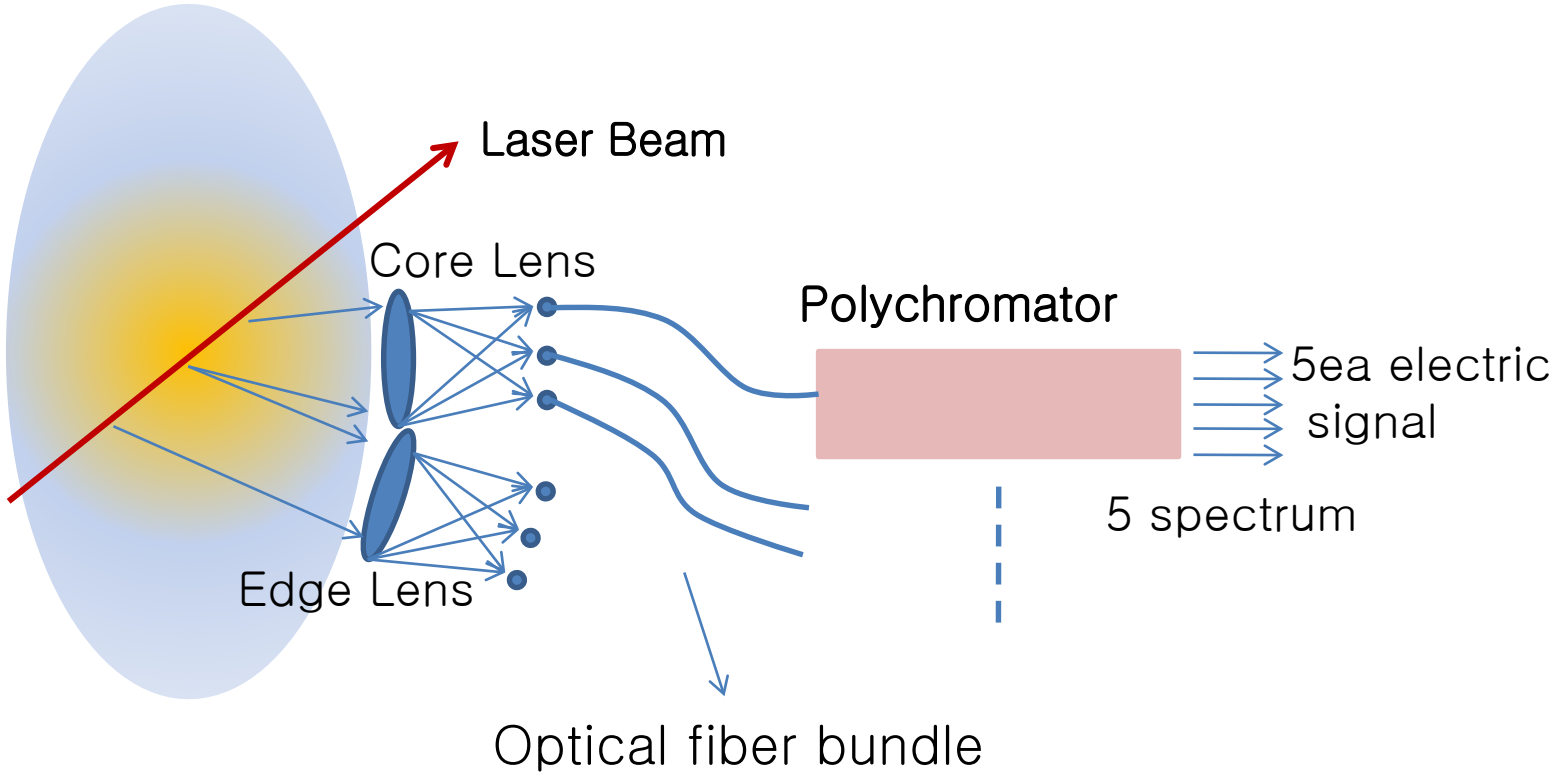
National Fusion Research Institute

Thomson Scattering System Intro.

Thomson system



Measurement of electron temperature(Te) and density(ne) profiles

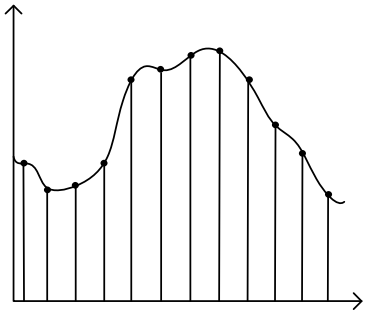
TS 5GSPS DAQ System

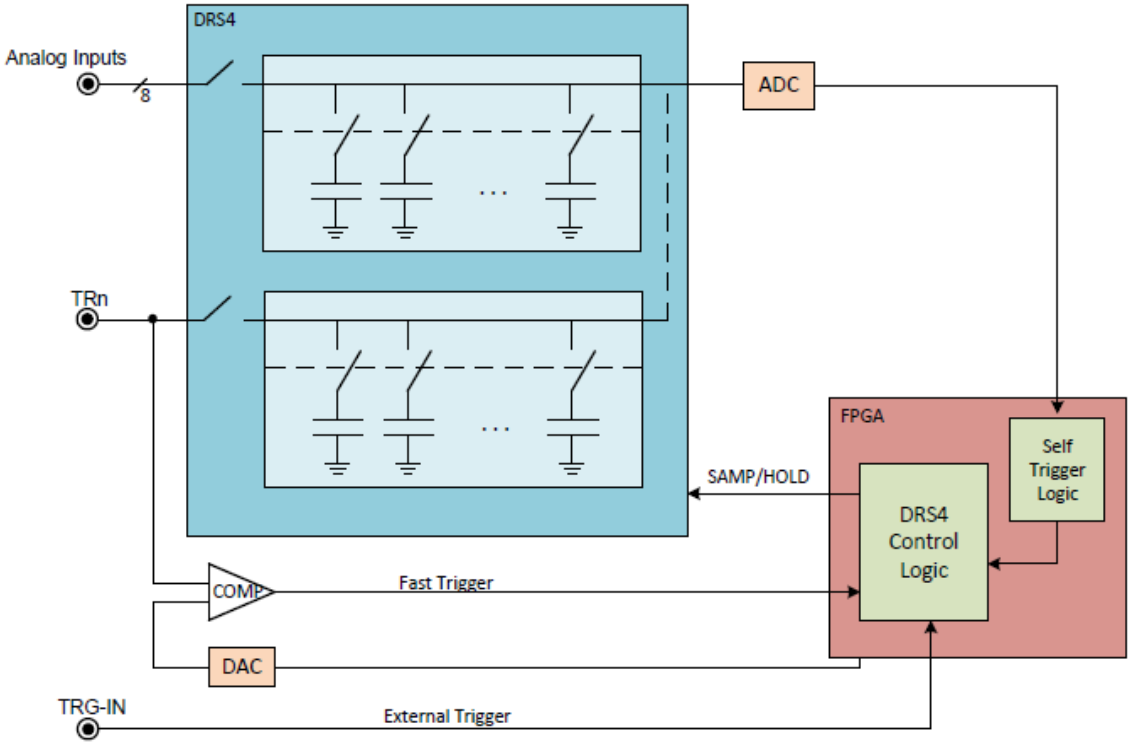
V1742(CAEN)

- 12-bit @ 5 GS/s
- Switched Capacitor technology based on the DRS4 chip (1024 capacitor cells per channel)
- 5, 2.5, 1 GS/s and 750 MS/s software selectable sampling frequencies
- VME64/VME64X (32 ch.), NIM (16 ch.) and Desktop (16 ch.) modules
- Analog inputs on MCX coaxial connectors
- 1 Vpp input dynamic range with programmable DC offset adj.
- Dead-time due to conversion: 110 μs (analog inputs only), 181 μs (TRn inputs)
- Memory buffer options: 128 events/ch; 1024 events/ch
- VME64/VME64X, USB and Optical Link communication interfaces
- Multi-board synchronization features (VME only)
- 16 programmable LVDS I/Os

TS 5GSPS DAQ System

Switched Capacitor Array(SCA)

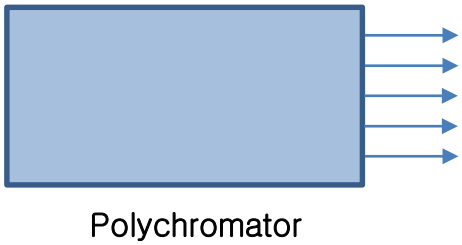




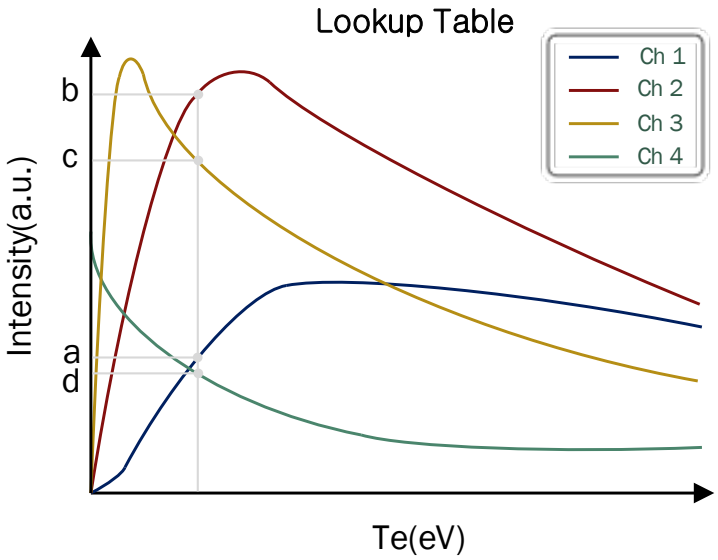
- The analog signal is collected in array of 1024 capacitors with 5GHz switching.
- After holding the collection, voltage values of each capacitor are sequentially acquired by ADC circuit.
- The information of the pulse shape and noise level is available.

Diagnostic Calculation Method

X-square method



Ch.	Intensity
1	a
2	b
3	c
4	d



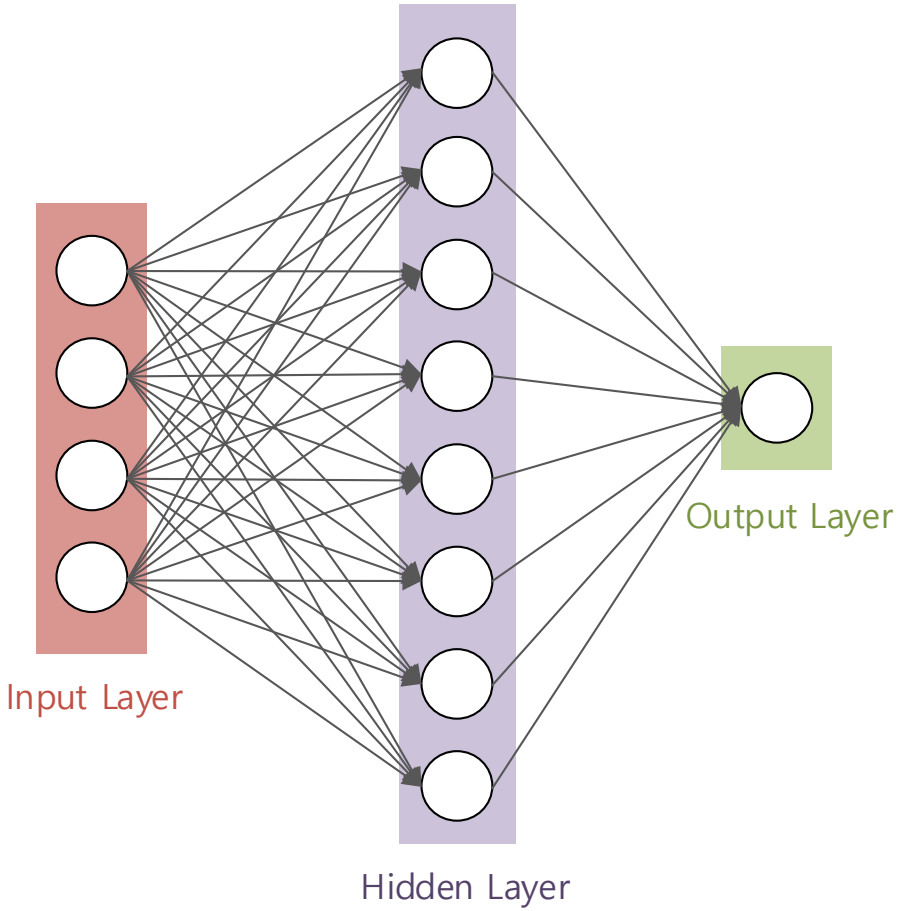
X-square method: $min_{Te}\ X^2 = \sum_{i=1}^{4} \omega \left(y^i_{data} - f^i_{Cal}(Te) \right)^2$

◆ Current status
- The diagnostic data is available after each plasma shot experiment.
- The diagnostic calculation takes few seconds.

◆ Problem: Increased data to be processed
- Raw data: 1data(QDC) => 1024 data(5GSPS), signal processing, integral
- Resolution of the lookup table: 1eV => 0.1eV

Diagnostic Calculation Method

Artificial Neural Network(ANN)*



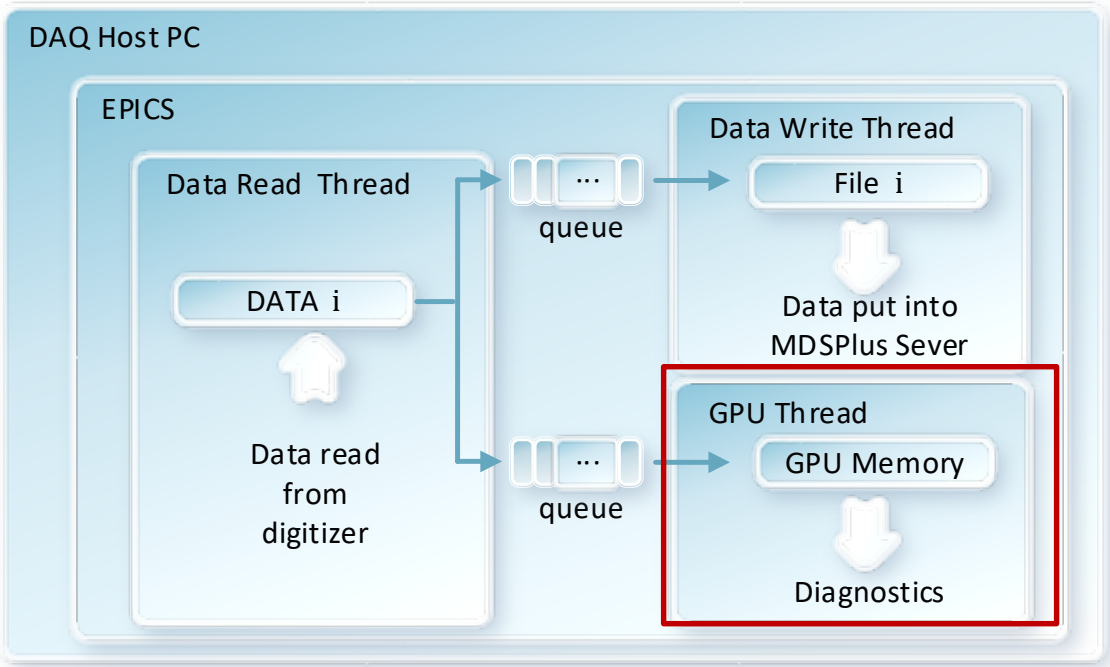
◆ ANN Feasibility Test*
- Optimized performance of ANN
  - 8 nodes of the hidden layer
  - Training cycles: $N=10^3$
- The computation time is 20 times faster than the X-square methods.

◆ Design of Computation Architecture
- Adoption of the ANN algorithm
- Real time operation: 20ms
- Compatible with TS DAQ program
- GPU based Computation Architecture
  - Parallel computation of multiple ANNs
  - Parallel computation of integration operation for each pulse signal
  - Reduction of CPU task load

* Seung Hun Lee, J. H. Lee, I. Yamada, and Jae Sun Park, "Development of a neural network technique for KSTAR Thomson scattering diagnostics", Review of Scientific Instruments, Vol. 87, 11E533. 2016.

Parallel Computation Architecture

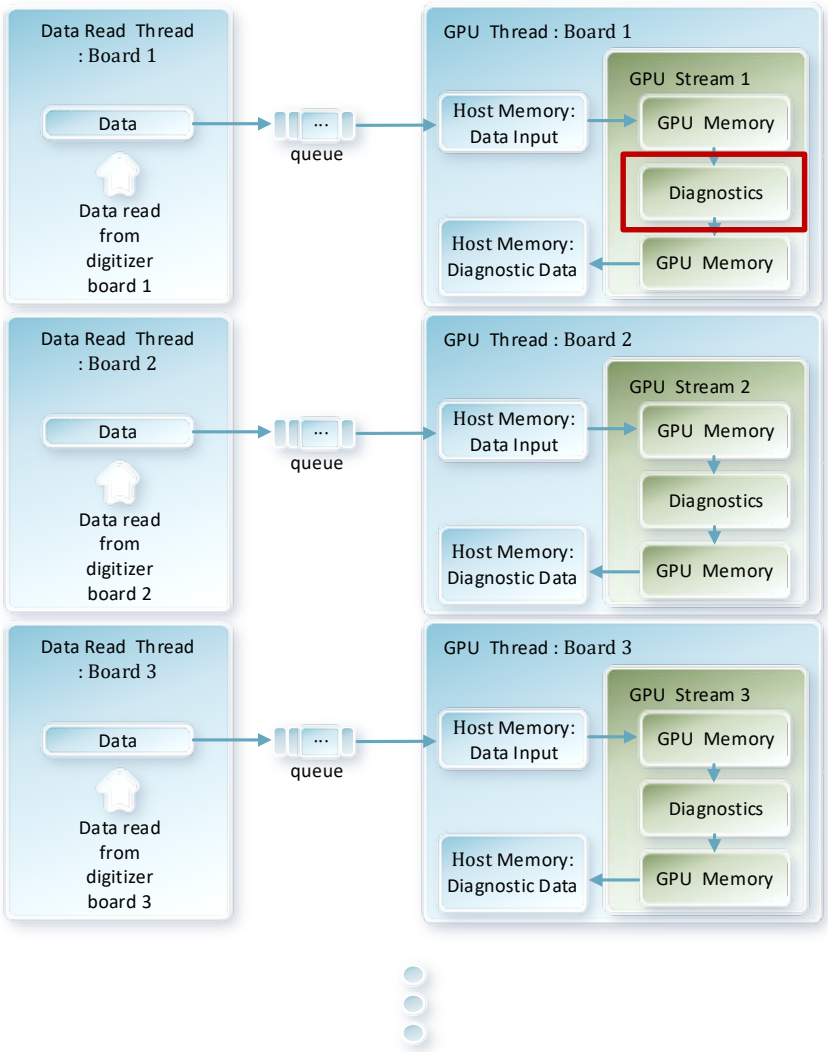
Overall Structure



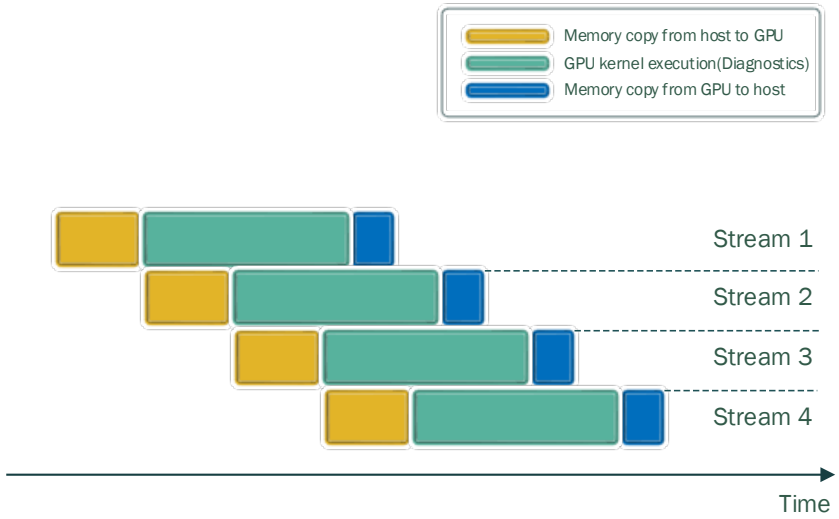
- EPICS framework
- Data read thread: Receive the raw data from digitizer
- Data write thread: Store the raw data in file => Put to MDSPlus server
- The GPU thread: Diagnostic calculation
- Queue: Ring buffer

Parallel Computation Architecture

Task Parallelization



CUDA Stream



◆ Task parallelization
- TS DAQ host PCs: TS Core, TS Edge
- Four digitizer boards(32ch/board) for each DAQ host PC
- The task of each digitizer is parallelized by using its own data read thread and GPU thread

◆ CUDA stream
- Support the task parallelization
- Task concurrency is enabled

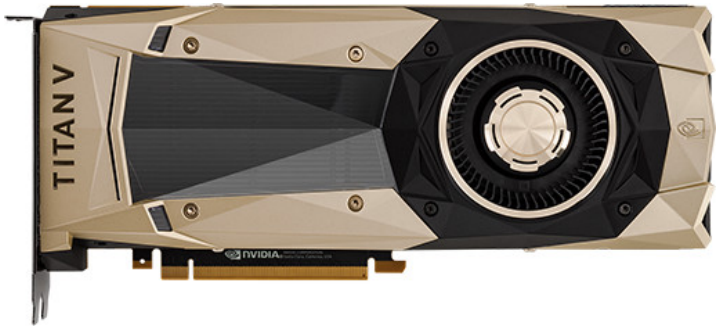
Parallel Computation Architecture

Parallelization of Diagnostic Calculation

- Total six ANNs are simultaneously calculated.
- Integral
  - 1 block /channel
  - 1024 threads / block
  - Total 24 blocks
- ANN(IN->HI)
  - 1 block / ANN
  - 4(IN) X 8(HI) threads/ block
  - Total 6 blocks
- ANN(HI->OUT)
  - 1 block / ANN
  - 8(HI) X 1(OUT) threads/ block
  - Total 6 blocks
- Method for signal processing is a research topic

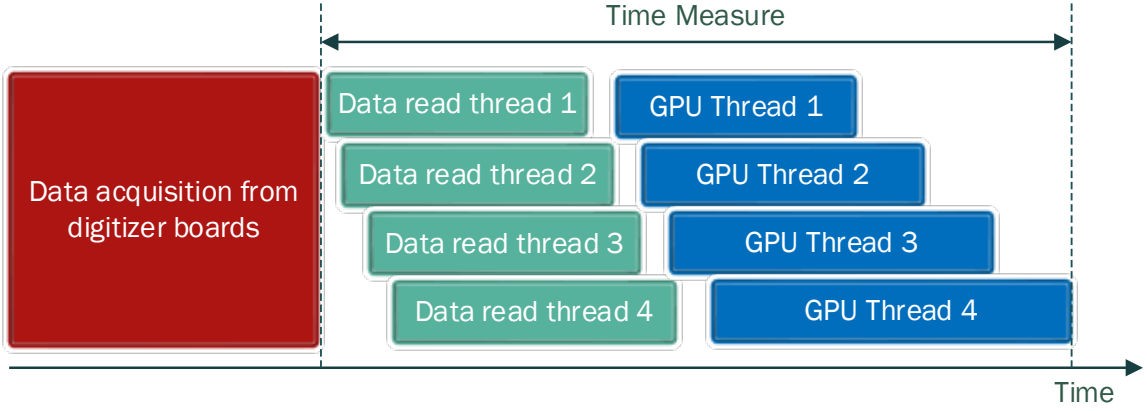
Feasibility Test

Test GPU



Specification	
Architecture	Volta
Memory Size / Type	12GB / HBM2
Memory Bandwidth	651.3GB/s
CUDA Cores	5120
FP32(float) performance	14.90 TFLOPS

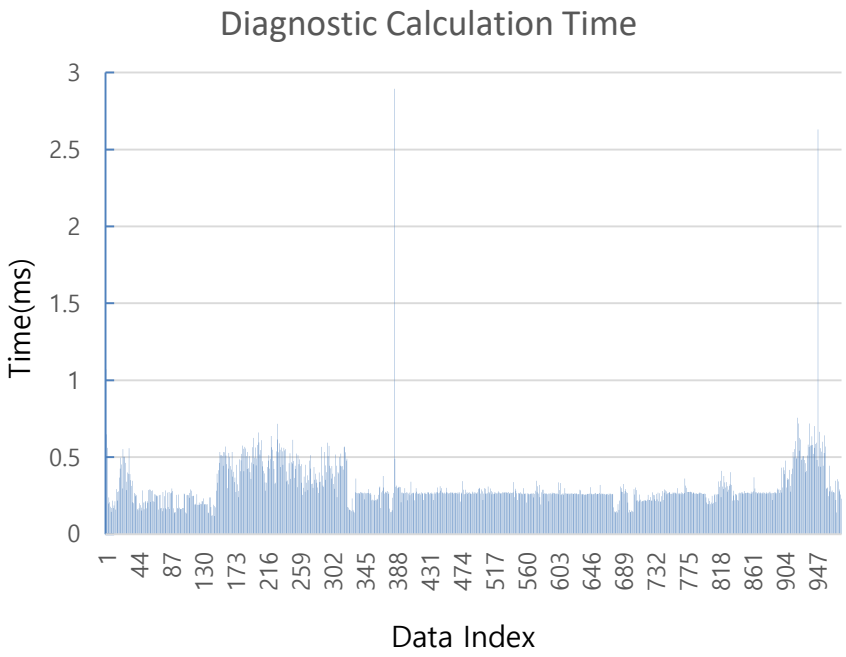
Test Conditions

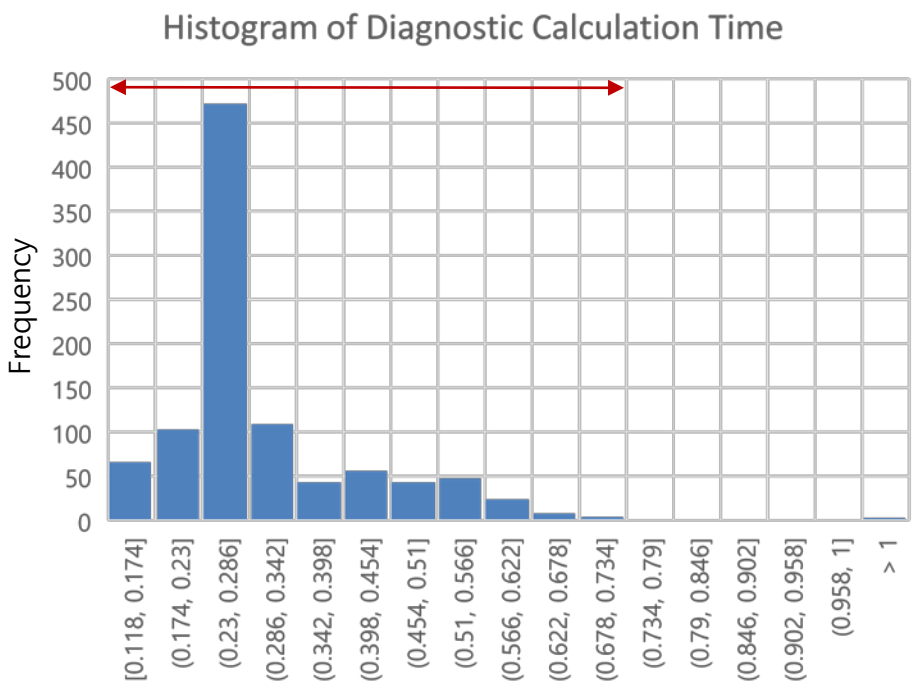


- Data acquisition and execution of data read threads are simulated by reading a sample data file. (Period: 50Hz)
- We measure the time length that all data read and GPU threads are completed.

Feasibility Test

Test Results: Diagnostic Calculation Time





- Average: 0.312 ms, Peak: 2.894ms
- Max frequency: [0.23 0.286]ms
- Expected calculation time range: [0.118 0.734]ms < 1ms

Conclusion & Future Works

◆ Conclusion
- 5GSPS DAQ system have been installed in KSTAR Thomson Scattering system.
- Diagnostics Method: X-square => ANN
- Task parallelization
  - Data acquisition => Diagnostic calculation
  - Multi-thread based programming
- Parallelization of diagnostic calculation
  - Calculation of each neural network is executed concurrently.
  - GPU based architecture (CUDA programming)
- Integration with EPICS frame work.

◆ Future Works
- Research Topic: signal processing of raw TS data
- New calibrated TS data => Learning ANN and evaluation
- Implementing the architecture in the TS DAQ system.

◆ Application
- Streaming the diagnostic data
- Feedback control

Thank You