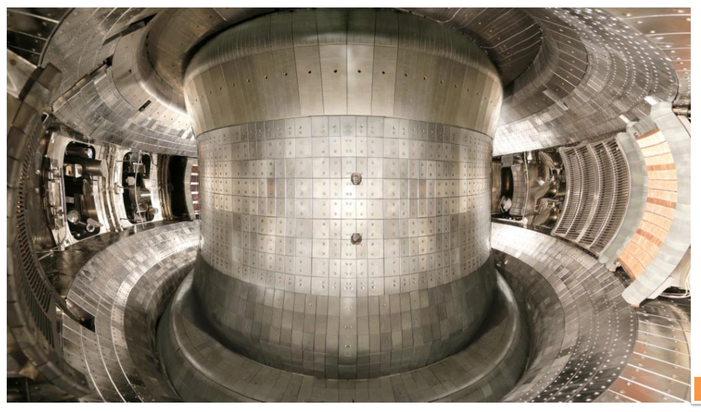
ASIPP
Institute of Plasma Physics, Chinese Academy of Sciences

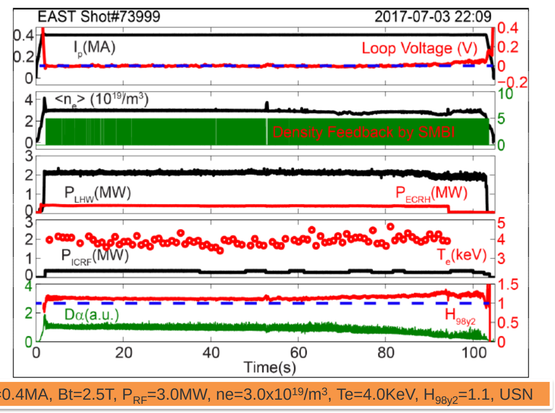
Upgrade of the Data Acquisition and Control System of Microwave Reflectometry on the Experimental Advanced Superconducting Tokamak

Fei Wen[1*], Haoming Xiang[1,2], Tao Zhang[1], Yuming Wang[1], Xiang Han[1], Hao Qu[1,2], Fubin Zhong[1,2]
Kaixuan Ye[1,2], Mingfu Wu[1,2], Gongshun Li[3,4], Shoubiao Zhang[1], Xiang Gao[1]
1. Institute of Plasma Physics, Chinese Academy of Sciences, Hefei, 230031, PR China;
2. University of Science and Technology of China, Hefei, 230026, PR China;
3. Advanced Energy Research Center, Shenzhen University, Shenzhen 518060, PR China;
4. Key Laboratory of Optoelectronic Devices and Systems of Ministry of Education and Guangdong Province, College of Optoelectronic Engineering, Shenzhen University, Shenzhen 518060, P.R. China.
*Email: wenfei@ipp.ac.cn, Tel: +86-551-65590405

Abstract Upgrade of reflectometry is ongoing on Experimental Advanced Superconducting Tokamak (EAST) for more comprehensive measurement of plasma density profile and fluctuation. The Data Acquisition and Control System(DACS) has been redeveloped to satisfy requirements of upgraded reflectometry. The PXIe-based DACS includes two 8-channel 14-bit 250MSPS digitizers and Ten 8-channel 14-bit 60MSPS digitizers . The data (1840MBytes/S) from digitizers is streamed to disk array (RAID 0) with data throughput capacity of 2.9 GB/S. Meanwhile, selected data is transported to a FPGA based real-time computing module, which utilize a pre-trained neural network to invert raw data to plasma density profile. Now the new reflectometry is being installed on EAST, and its performance will be tested in experimental campaign of 2018.

EAST





Ip=0.4MA, Bt=2.5T, P_{RF}=3.0MW, ne=3.0x10^{19}/m^3, Te=4.0KeV, H_{98y2}=1.1, USN

The Experimental Advanced Superconducting Tokamak (EAST) is an experimental superconducting tokamak magnetic fusion device in Hefei, China. It is the first tokamak to employ superconducting toroidal and poloidal magnets. It aims for plasma pulses of up to 1000 seconds. On July 3, 2017, EAST became the first tokamak to successfully sustain H-Mode plasma for over 100 seconds at ~50 million Kelvin. (from Wikipedia)

Microwave Reflectometry

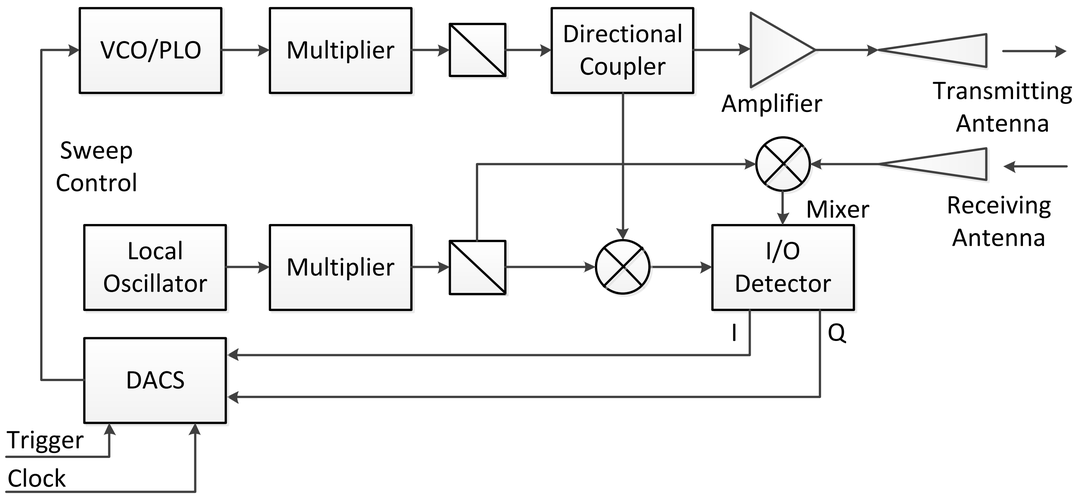


Fig. 1. Typical architecture of microwave reflectometry

Fig. 1. has shown the typical architecture of microwave relflectometry. The reflectometry employ voltage controlled oscillator (VCO) or phase locked oscillator (PLO) as microwave source. The generated signal was lunched to plasma and reflected at the cut-off layer of the plasma. The reflected signal was inverted to intermediate frequency signal, which is demodulated by I/Q detector to acquire its phase, frequency and amplitude. The DACS acquires the I/Q signal under the control of trigger and clock signal from the central controller . For the swept frequency reflectometry, DACS outputs a control signal to the VCO. On the EAST, the DACS need to take care of 9 reflectometrys listed in Table I.

TABLE I
OPERATING BAND AND MODE OF UPGRADED REFLECTOMETRY SYTEM

	Band	Mode	Frequency	Target
1	K and Ka band (20-40 GHz)	O mode	Fixed	Fluctuation
2	U band (40-60 GHz)	O mode	Fixed	Fluctuation
3	V band (50-75 GHz)	X mode	Fixed	Fluctuation
4	W band (75-110 GHz)	X mode	Fixed	Fluctuation
5	Q band (32-56 GHz)	X mode	Swept	Profile
6	V band (48-76 GHz)	X mode	Swept	Profile
7	W band (72-110 GHz)	X mode	Swept	Profile
8	U band (40-60 GHz)	O mode	Swept	Profile
9	E band (60-90 GHz)	O mode	Swept	Profile

Data Acquisition and Control System

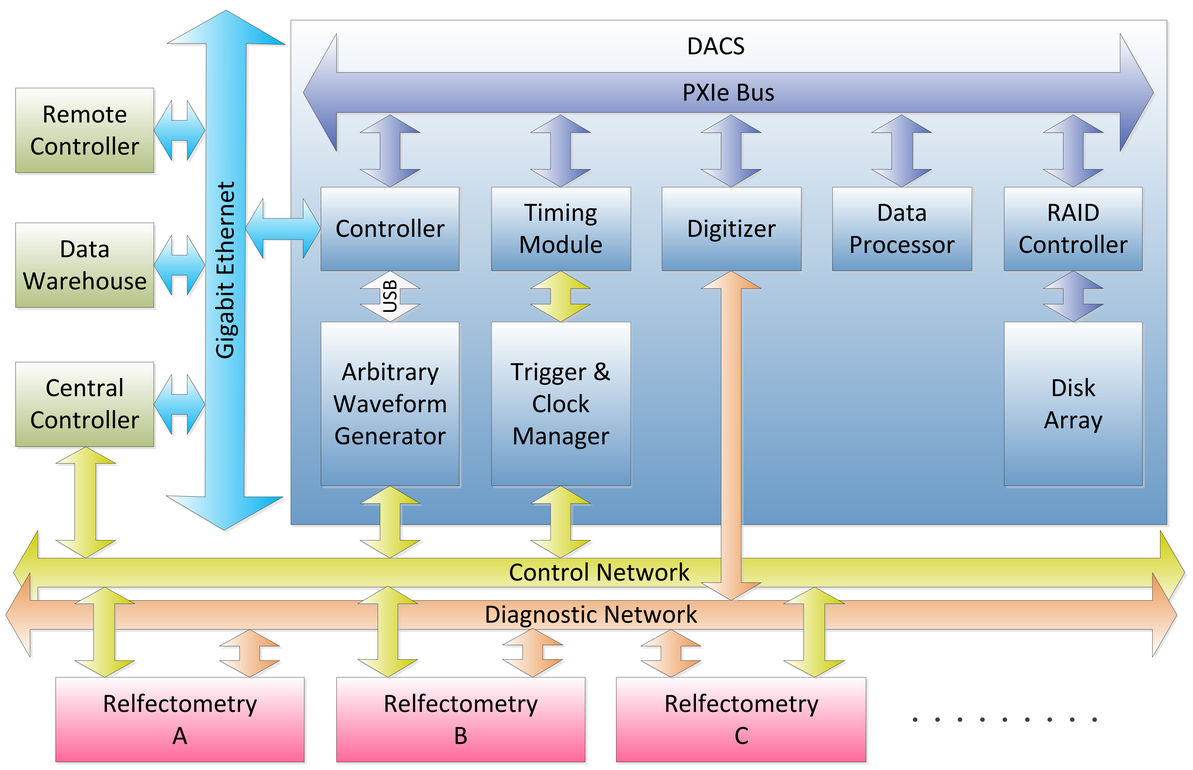


Fig. 2. Architecture of DACS

The DACS is a COTS based system, and most of the devices are from National Instruments. All the modules including digitizers, timing module and disk array are connected to the controller via PXIe bus which provides 24GB/s total data bandwidth and 8GB/S data bandwidth for one slot. A dedicated arbitrary waveform generator outputs swept voltage (0-20V) to controls the VCO of reflectometry. There is a trigger and clock manager used for synchronizing the DACS with the central controller.

High-Speed Data Streaming

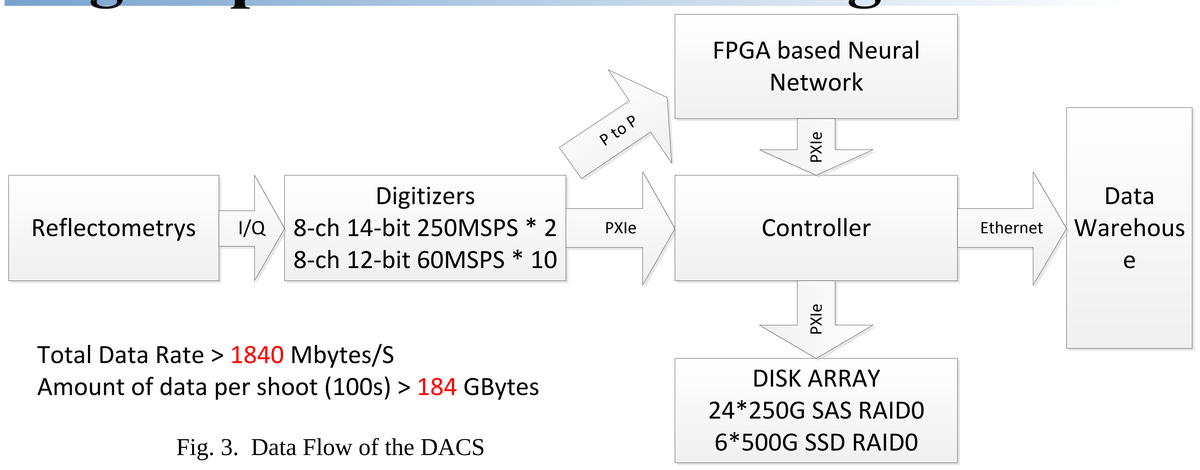


Fig. 3. Data Flow of the DACS

The DACS employs 12 digitizers to acquire data. The total data rate reaches a staggering 1840 MBytes/S. During a shoot of EAST, there are a lot of transient events that need to be record, like the ELMs, L-H transition. The DACS have to record all signals during the shoot. When a shoot lasts over 100 seconds, the amount of data will reach 184 GBytes. The DACS provide a high continuous data throughput rate of 2.9 GByts/S and data storage capabilities of 5.7 TBytes . The DACS will upload the data to data warehouse via Gigabit Ethernet between the shoots, so it works well for the high data rate job. To satisfy the real-time control requirements, a FPGA based neural network module is applied to process selected data in real time.

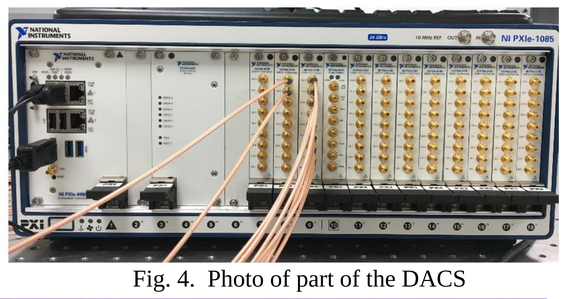


Fig. 4. Photo of part of the DACS