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OUTLINE OF DAQ FOR 30 GHZ HIGH POWER PROCESSING

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System overview

The 30 GHz high power test stand of CTF3 will require a sophisticated data acquisition and processing system (DAQ) to allow in a 1st stage

- Simultaneous acquisition of all relevant data on every CTF3 machine pulse for repetition rates of up to 50 Hz
- data reduction for recording the processing history
- producing interlock conditions for the drive beam in-between two pulses

In a 2nd stage the functionality has to be extended for simultaneous and automatic processing of PETS and the device under test. In this stage the system will control beam parameters like pulse length and current as a function of a pulse to pulse analysis of the various measured signals.
A schematic layout of the test stand with the various signals is shown in figure 1.

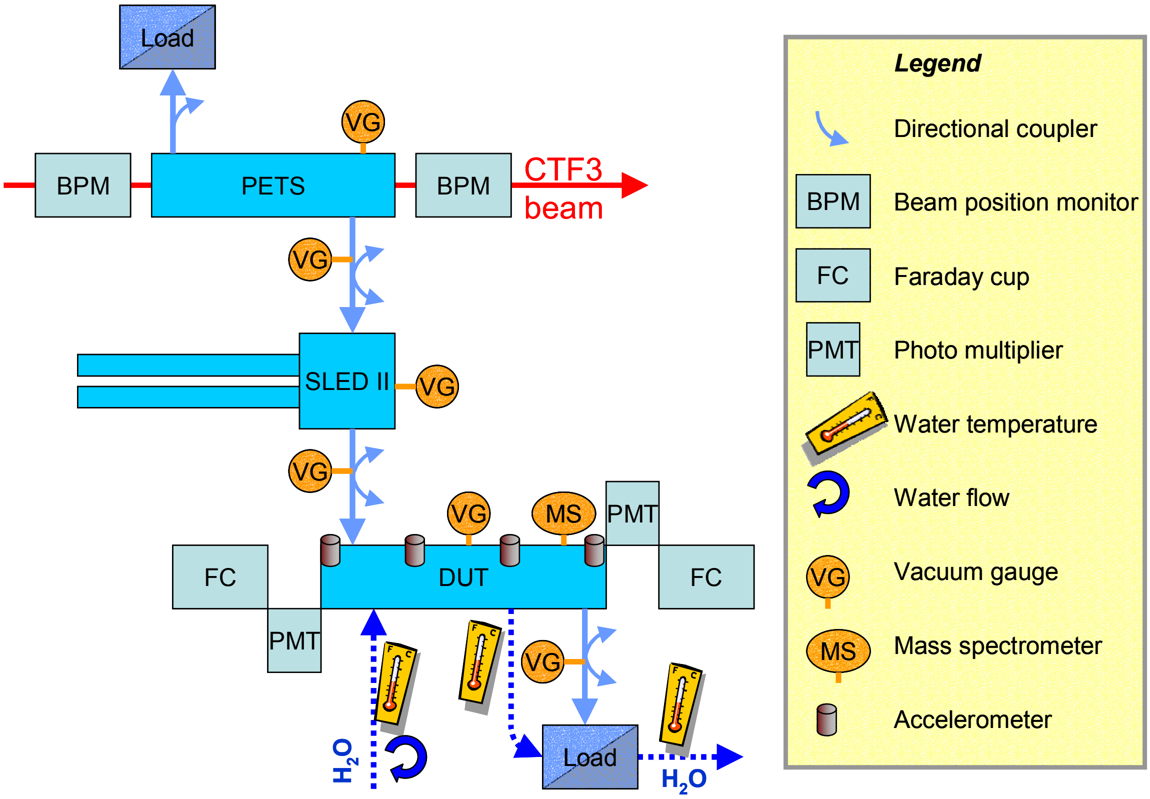

Figure 1

Schematic layout of CTF3 30 GHz high power test stand, indicating the various measuring quantities. PETS stands for power extraction and transfer structure. SLED II is a RF pulse compression system and the device under test (DUT) will be a CLIC accelerating structure prototype or any other CLIC high power RF component.

RF signal capture

For the processing of the RF signals, a two stage down-conversion seems most practical. In the first stage the 30 GHz signals are down-converted to 2 GHz IF using the existing system from CTF II. In a second stage the signals are mixed with a 2 GHz LO (again phase locked to the RF master clock) in phase and in quadrature to get the amplitude and phase along the RF pulse. Therefore each RF signal from a directional coupler will require two digitiser channels. All LO signals have to be phase-locked with the RF master-oscillator of CTF3. From past experience with CTF II and elsewhere, it is known that a typical RF-breakdown takes about 5 ns. To utilize methods similar to those established at NLCTA for locating the breakdown in the structure, a rise time of 2 ns or better and a phase resolution of 10^o or better is required. The fast vector as defined below is a minimum requirement for the digitiser to achieve this resolution.

The system should be adapted to deal with power flows from 100 kW to 200 MW in the waveguides. Pulse-length can vary in the range 20-1500ns.

These signals belong to the principal signals to be used for automated processing in the 2nd stage as described above.

Faraday cups

The up- and down-stream emitted currents from the DUT can be measured with Faraday cups (FC). FC's will allow measurements without low frequency cut-off over a very large bandwidth. The existing CTF II faraday cup design can be used. The emitted dark currents can vary over a very large range in the order of 0.1 mA-10 A, with risetimes in the order of a few ns, therefore a fast logarithmic amplifier together with a fast 8 bit digitiser seems best suited for data acquisition. Pulse-length can vary in the range 20-1500 ns. These signals belong to the principal signals to be used for automated processing.

BPM signals

The beam position and intensity monitors (BPM) up and downstream of the PETS provide position and intensity signals for the drive beam. The BPM's are of the standard CTF3 linac type.

Although these signals are already digitised in the CTF3 control system, it seems practical to digitise the intensity signals of the BPM's independently in the 30 GHz DAQ to monitor the performance of the PETS as a function of drive beam intensity and transmission. The BPM intensity signals have a bandwidth of about 50 MHz. Pulse-length can vary in the range 20-1500 ns. These signals are important for machine protection, interlock conditions have to be checked on a pulse to pulse basis.

Photomultiplier signals

Photomultipliers (PM) detect the light emitted during some of the breakdown events. Their signals may are useful to get a better understanding of the breakdown mechanism. The light signal risetime is similar to that of the emitted current. Pulse-length can vary in the range 20-1500 ns. Whether a logarithmic amplifier or a linear amplifier between PM and digitiser is more appropriate has to be determined experimentally.

Accelerometers

Accelerometers can measure the propagation of the mechanical shockwave created by an RF breakdown. At SLAC and to a smaller extend at CTF II they have been used to determine breakdown locations. They may well provide information on the damage potential of RF breakdown events. Their bandwidth is typically limited to ≤100 kHz

The mechanical vibration after a breakdown can last for several ms but the interesting part is the signal start time, which is, via the sound velocity (typically 2mm/µs in copper), related to the breakdown location.

Vacuum gauge

The gauge signals are slowly varying and one readout in-between two machine pulses is sufficient. The presently used gauge controller provide a 0-10V output proportional to the logarithm of the pressure. Alternatively the ion pump currents could be read. The pressure range of interest is 10^{-10} -10^{-6} Torr. These signals belong to the principal signals to be used for automated processing

Residual Gas Analyser

A residual gas analyser (RGA) allows determination of the gases released from the RF structure surface during breakdown events (at least for gases of low atomic mass numbers). These measurements are useful to get a better understanding of the breakdown mechanism. How the RGA signals can be digitised depends on the mass spectrometer. For a fast sweeping RGA with analog output one complete sweep with a few ms duration digitised with a speed ≥100 kS/s can be envisaged. Sufficient resolution can be obtained either with a logarithmic amplifier and a ≥8 bit waveform digitiser or a ≥12 bit digitser with linear amplification.

Waterflow and temperature

These signals will allow for calorimetric measurements of RF power levels. The required resolution remains to be determined. These signals are slowly varying. One readout in-between two machine pulses is sufficient.

Digital treatment

The design of the DAQ has to be done from the beginning in close collaboration with the accelerator controls group to allow a smooth integration in the CTF3 controls architecture. For the demanding task of defining and programming this system, appropriate manpower has to be found.

The signal digitisers have to be triggered from the CTF3 timing synchronous with the beam pulse. The clocking of the ADC's should be done with a clock synchronous with the master oscillator of the CTF3 timing system.

The system has to be fast enough to cope with repetition rates of up to 50 Hz and pulse length from 20 ns to 1500 ns. The signals described can be grouped in four types:

Fast vector	requires ≥8 bit resolution, ≥500 MS/s and ≥1 kB data per pulse
Semi fast vector	requires ≥8 bit resolution, ≥100 MS/s and ≥0.2 kB data per pulse
Slow vector	requires ≥8 bit resolution, ≥500 kS/s and ≥1 kB data per pulse
Scalar	requires ≥12 bit resolution, one data point per pulse

A summary of the various signals and the type is given in table1. From the table, it can be readily estimated that about 25 kB of data are obtained per machine pulse. If all of this has to be recorded, 36 GB of data would be produced in one 8h shift of 50Hz operation. Therefore the stored data has to be reduced to very few summary numbers for normal pulses and appropriate algorithms have to be developed to detect pulses with anomalous behaviour, for which complete data sets have to be saved for later analysis. The system has to be sufficiently flexible to be upgraded in a 2nd stage to an automated RF processing system.

The system has to treat all signals on every machine pulse. Treatment types are conversion of Real and Imaginary part of RF signals into amplitude and phase, integration, pulse-length determination, minimum/maximum peak detection and application of calibration factors. The results of these operations will have to be compared with preset threshold values. Exceeding a given threshold value can lead to a beam interlock condition.

Signal	$N_{Channel}$	Type	Characteristics	Needed for		
				Automated processing	Machine protection	Processing history
30 GHz RF signals	14	Fast vector	Linear, bipolar	+		+
Faraday cups	2	Fast vector	Logarithmic	+		+
PM	2	Fast vector	Linear, unipolar			+
Drive beam BPM's	2	Semi-fast vector	Linear, unipolar		+	+
Cooling water flow	1	Scalar	Linear, unipolar			+
Cooling water temperature	3	Scalar	Linear, unipolar			+
Vacuum gauge	6	Scalar	Logarithmic	+		+
RGA	1	Slow vector	Logarithmic ?			+
Accelero-meter	4	Slow vector	Linear bipolar			+

Table 1 Summary of acquisition channels