Klystron Lifetime Management System

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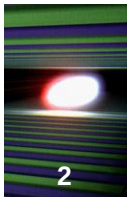
FLASH Seminar

European XFEL

Outline



- Introduction to KLM
- Protection and measurement functions
- Installation at Klystron test stand
- FPGA implementation
- DOOCS server and operation panels
- Results
- Conclusion
- Future plans

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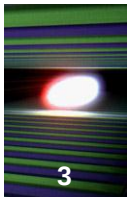
Introduction to KLM



- The klystron is a specialized linear-beam vacuum tube

XFEL: Multi Beam Klystron 10 MW, 10pps, 1.7 ms HV and 1.5 ms RF at 1.3GHz

Very expensive device!

Lifetime of the tube should be in excess of 60,000 hours

Dispenser cathode with beam loading of 2.A/cm^2 can provide average lifetimes of 145,000 hours!

Klystrons undergoing frequent failures,

- There is a few factors which can reduce lifetime of the tube.
  - Bad vacuum indicates ions current, RF and HV breakdown.
  - Gun arc can disrupt the cathode electrode and anode surface and can pollute the HV insulator and the active surface of cathode.
  - RF breakdown destructs cavity surface and can pollute RF window that increases probability of RF breakdown.
  - Work in deep saturation: beam loss, bad vacuum..

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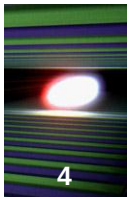
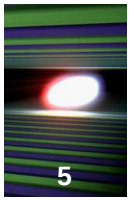
Introduction to KLM



- To prevent occurrence of the destructive factors the fast interlock is required.
  - If klystron parameters are over normal values, RF driving power or/and high voltage should be switched off.
  - System should detect exceptional events and react as fast as possible in order to prevent any damage that could be made. Reaction time: ~200ns.
  - Tube recovery procedure should depend on the kind of event.
- Klystron Lifetime Management system is the fast interlock and measurement system.

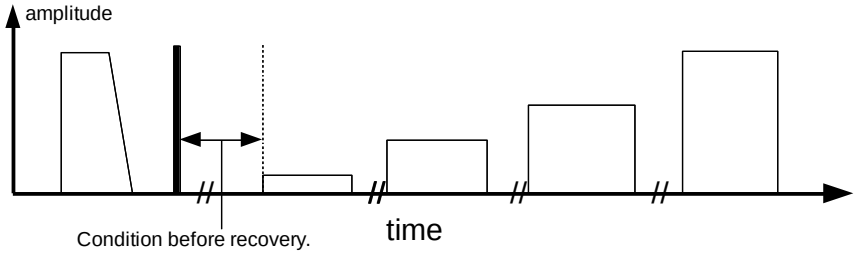
Protection and Measurement Functions



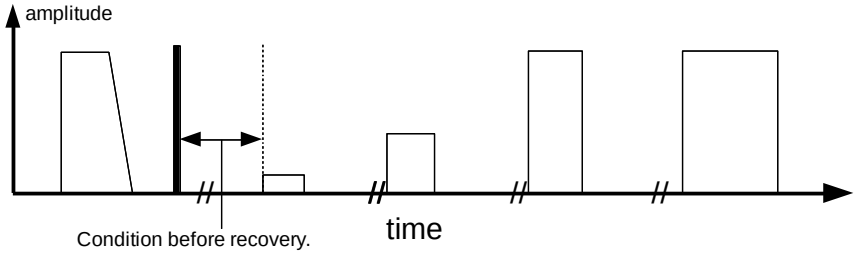
- Protection functions:
  - Correspondence of input and output power, RF breakdown inside tube detection;
  - Reflection power check, to high reflection power;
  - Saturation check, to high input power;
  - High voltage breakdown;
  - Bad vacuum detection;
  - Gun arc detection;
  - In case of event RF driving signal is switched off and recovery mode is run after it.
- Measurement functions:
  - Power and phase at klystron outputs and input measurement;
  - High voltage and klystron current measurement;
  - Partial discharge measurement;
  - Vacuum measurements;

Recovery Modes

- We use recovery modes to reduce damages that could be made when maximum power is on after error and error event is still on. E.g. slow ions.



- Waveguide breakdown recovery



- Window or tube breakdown recovery.

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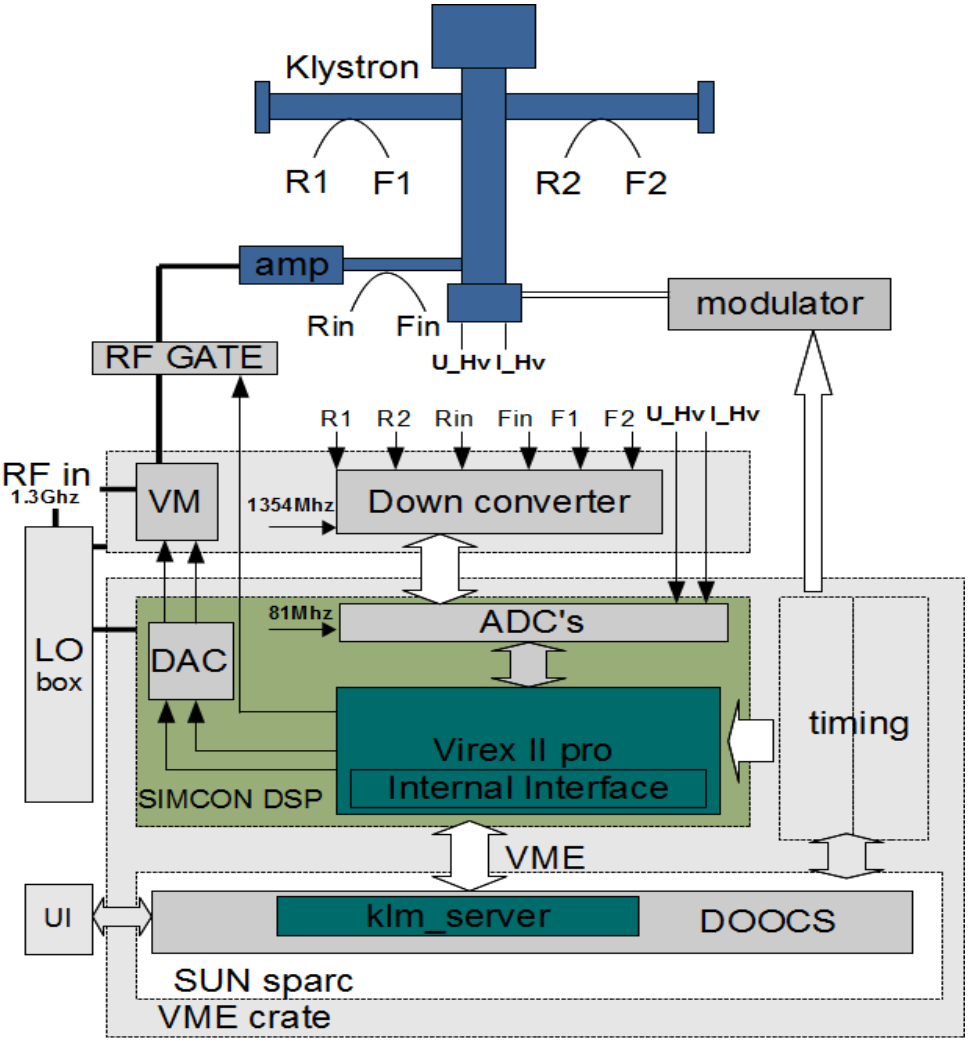
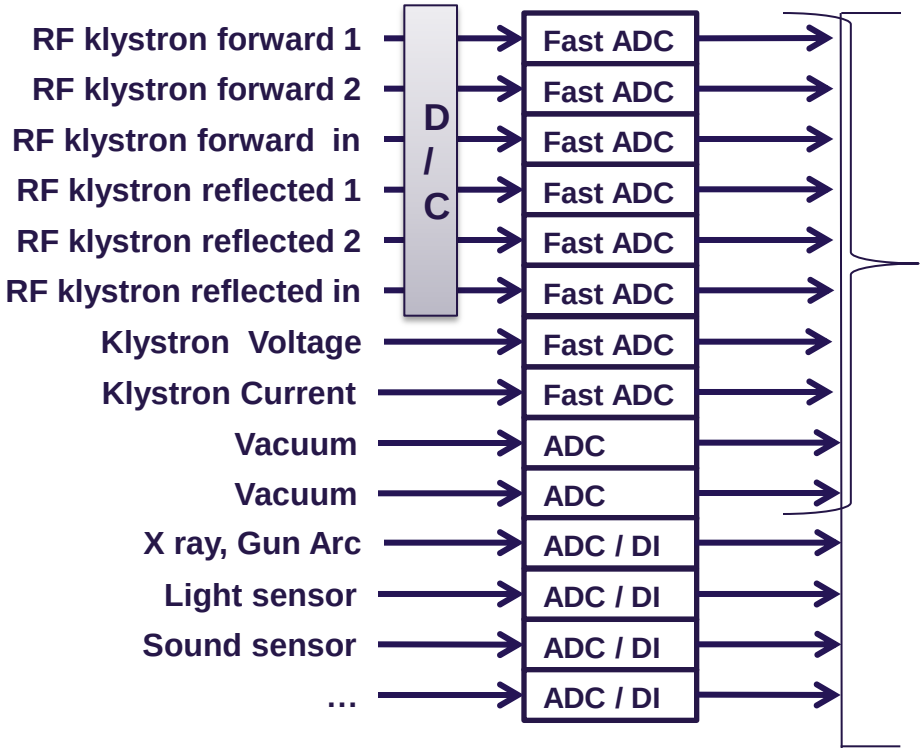
Installation at klystron test stand

- System based on VME.
  - Components:
    - SIMCON DSP
    - CPU: SUN Sparc;
    - Vector modulator;
    - RF gate;
    - DW RF 1300Mhz > IF 54Mhz;
    - LO box 1354Mhz, 81Mhz;
    - Timing board

- R1 – reflected power at first klystron arm;
- R2 – reflected power at second klystron arm;
- Rin – reflected power at klystron input;
- Fin – forward power at klystron input;
- F1 – forward power at first klystron arm;
- F2 – forward power at second klystron arm;
- U_HV – klystron high voltage;
- I_HV – klystron current;



Signals for protection



- 6 RF with fast low latency ADC
- 2 analog with fast low latency ADC
- 2 – 6 analog with normal ADC
- 0 – 4 digital signals

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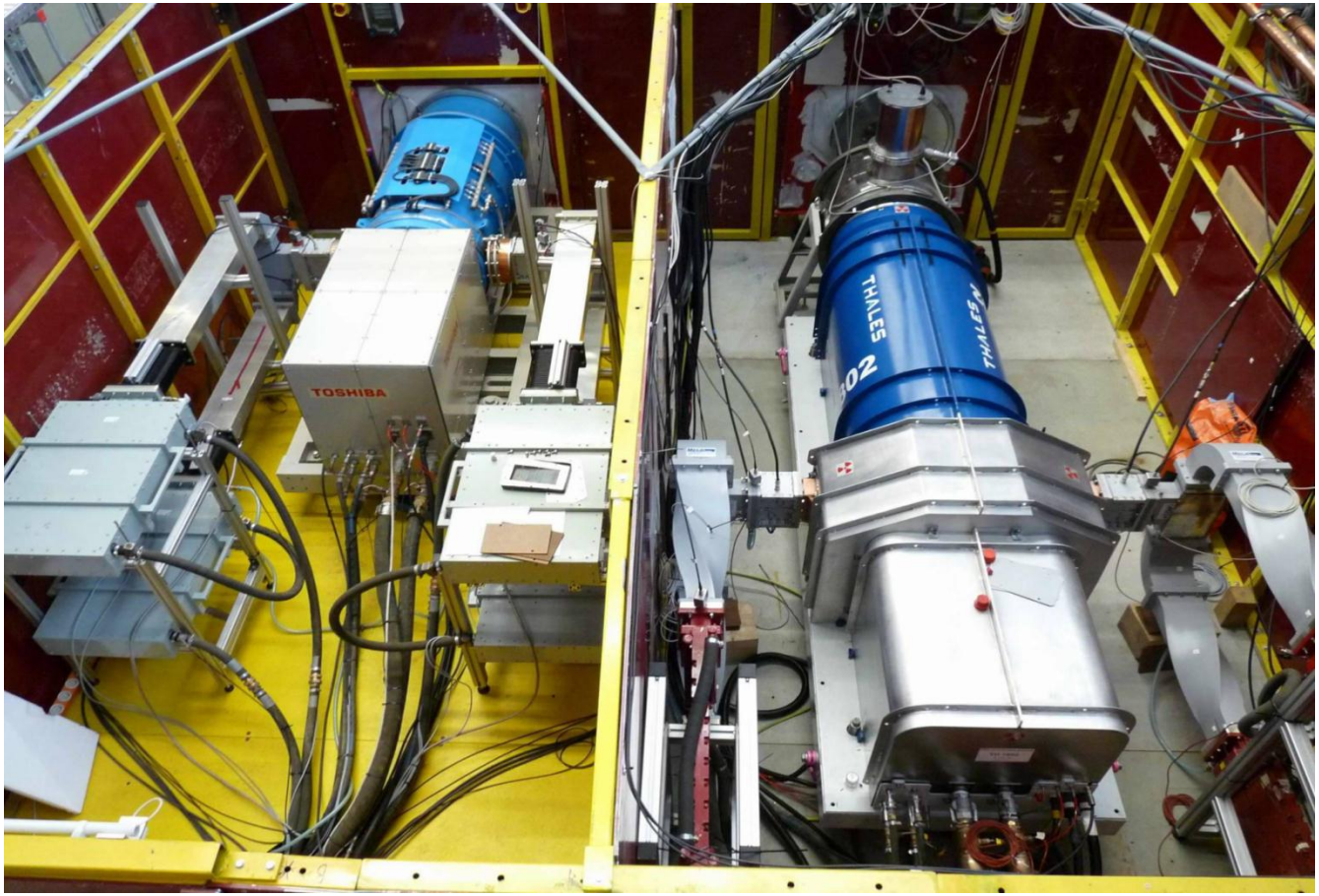
Klystrons test stand



Klystrons at test stand

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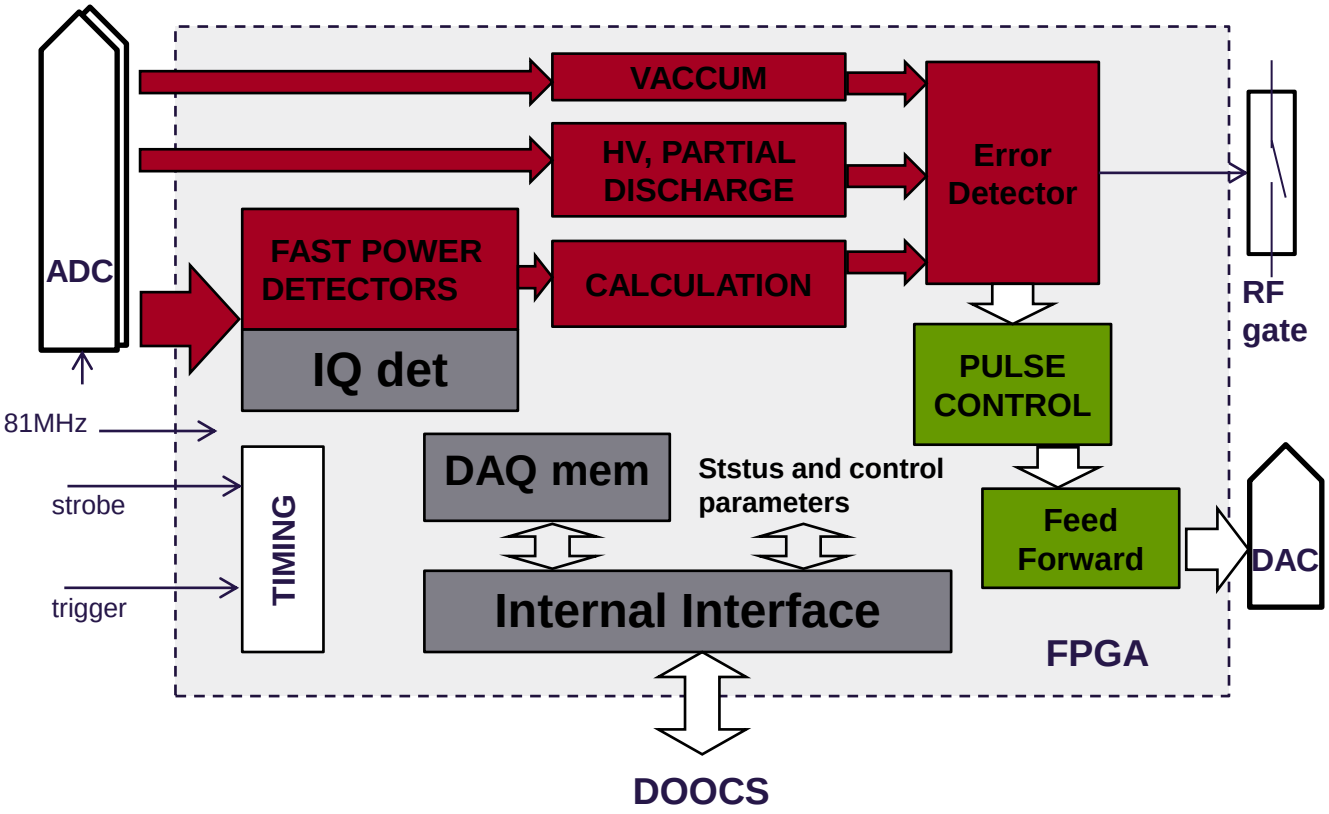
FPGA implementation



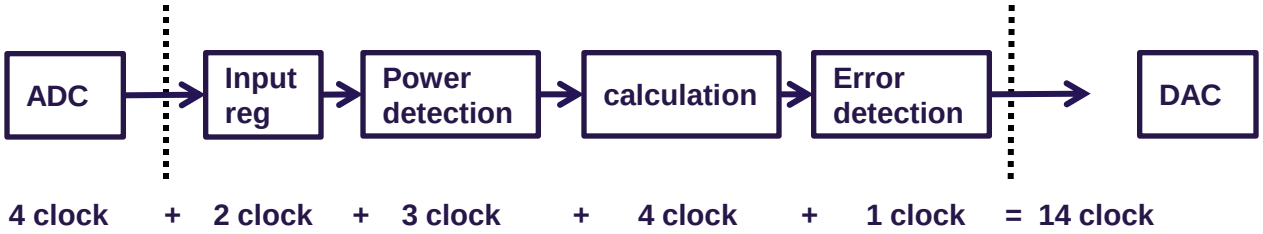
- Protection modules
- DAQ modules
- Forward and recovery modes modules

Block diagram of FPGA components

Ddelay path of event detection

Implementation on SIMCON

- All calculations are done in a pipeline



- Every clock cycle caclulation is done,
- Delay of error detection is 14 clocks (10 clock of FPGA)
- For 81 MHz IF clock 14 * 12 = 168 ns (+ DAC or RF gate) of delay

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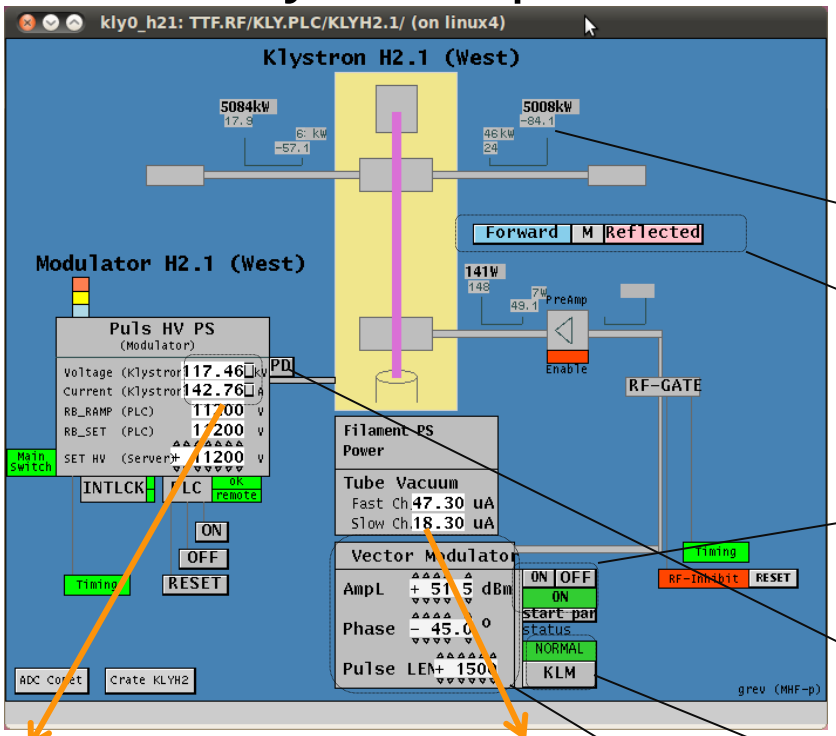
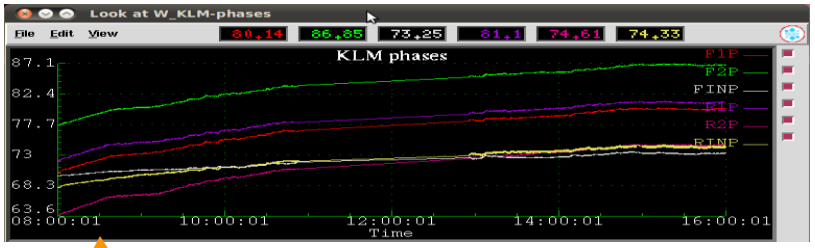
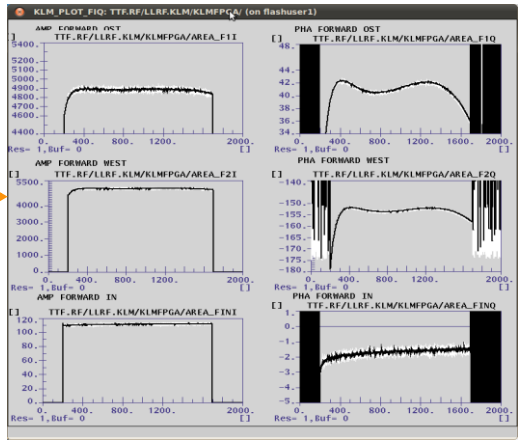
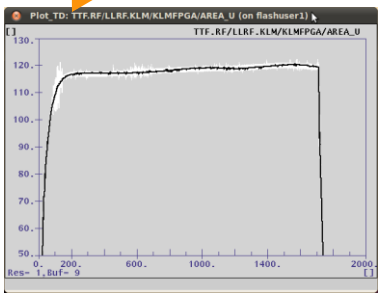
DOOCS panels

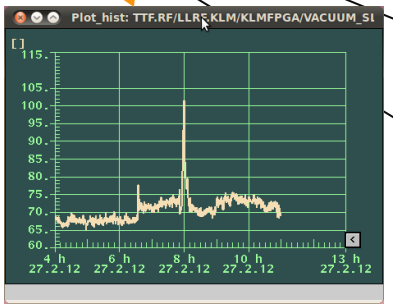
- Main klystron operation window.

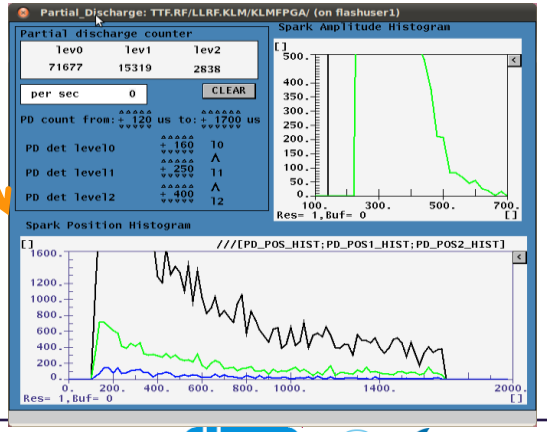












Power and phase measurement

Buttons for display current output power plots

Buttons for switch on and off RF signal and set startup parameters.

Partial discharge.

State of KLM system and button for main KLM window.

Vector modulator settings.

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DOOCS panels

Error counters

Enable protection functions.

State of current error state

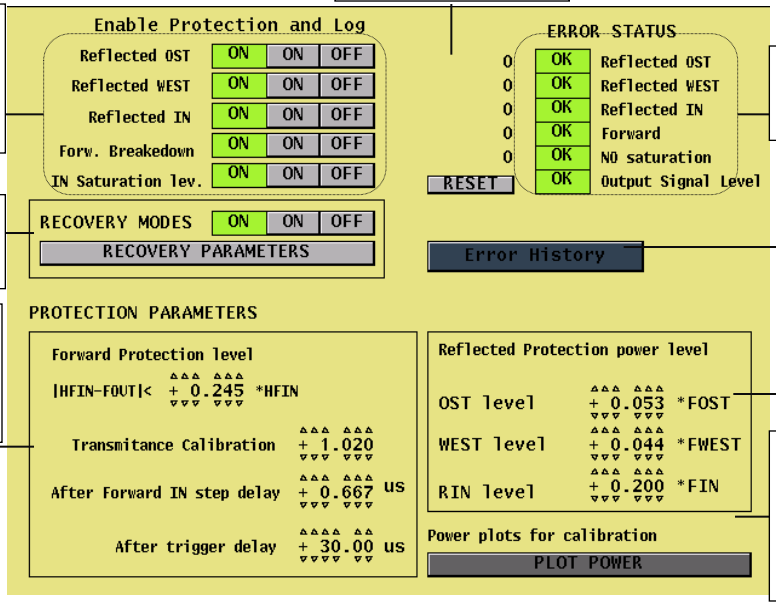
Recovery parameers.

Error history plots.

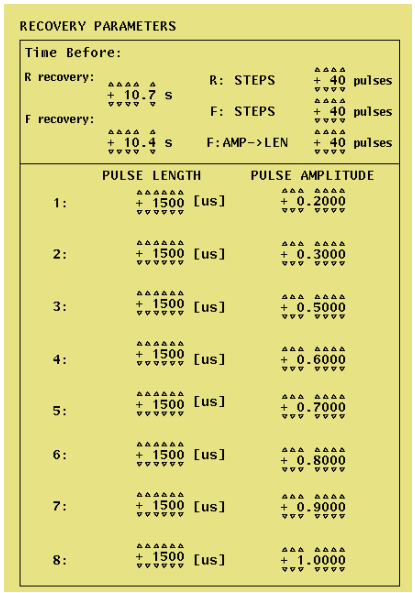
Parameters for forward protevtion.

Parameters for reflected protevtion.

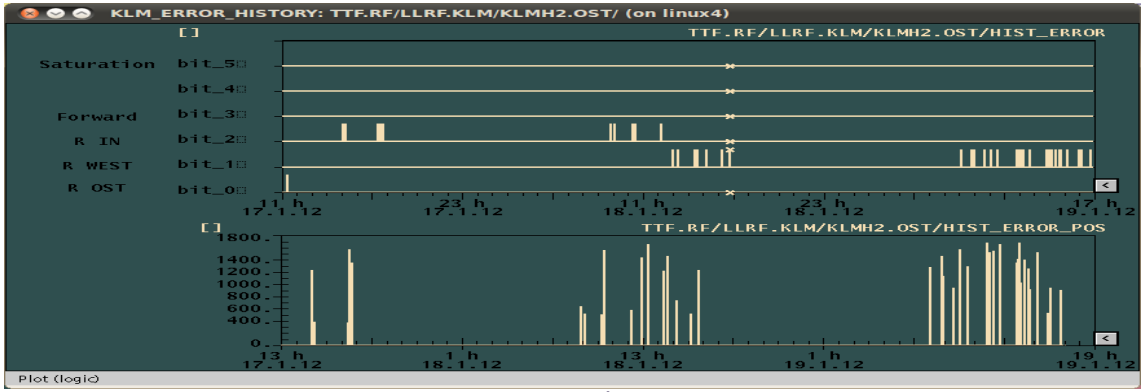
Plots of power for calibration from calculation and power detectors.



Main KLM control panel.



Recovery parameters



Error history

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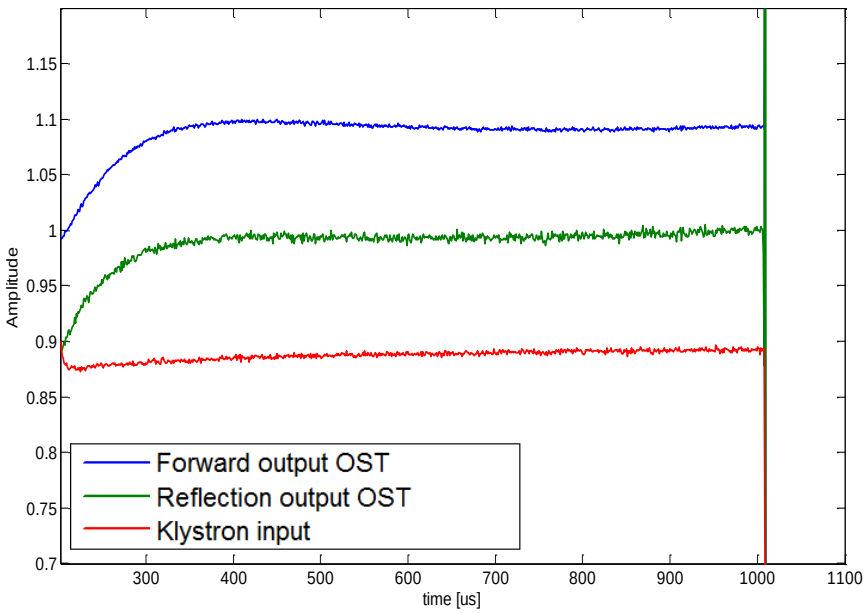
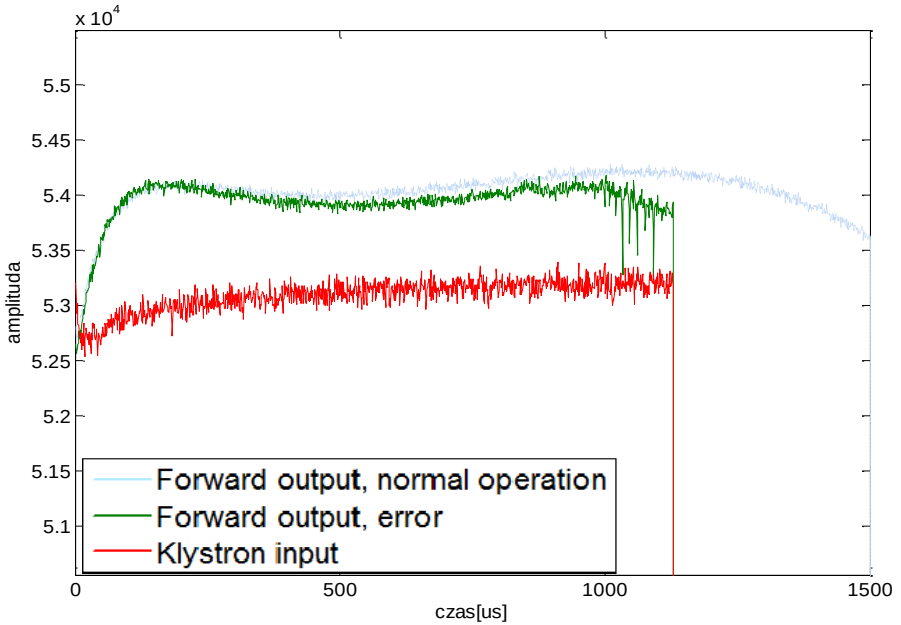
Results

In case of event all measured data is stored on HD for future analysis.

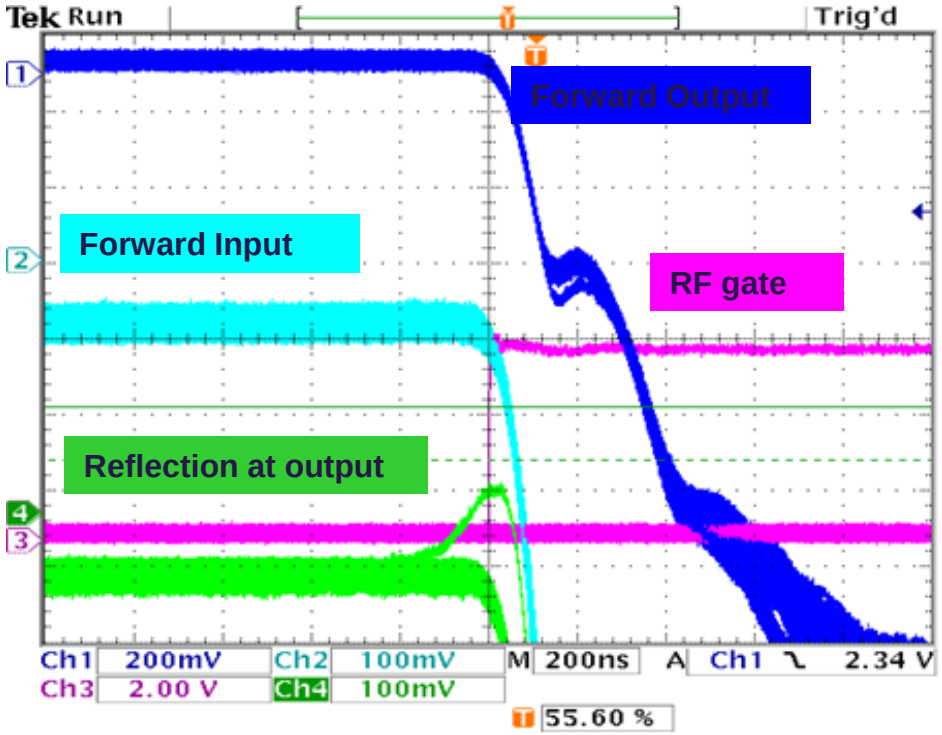


To high reflection event detection.



Forward power breakdown event.

Reaction of KLM system implemented on SIMCON is: 200ns – 250ns



To high reflection event detection.

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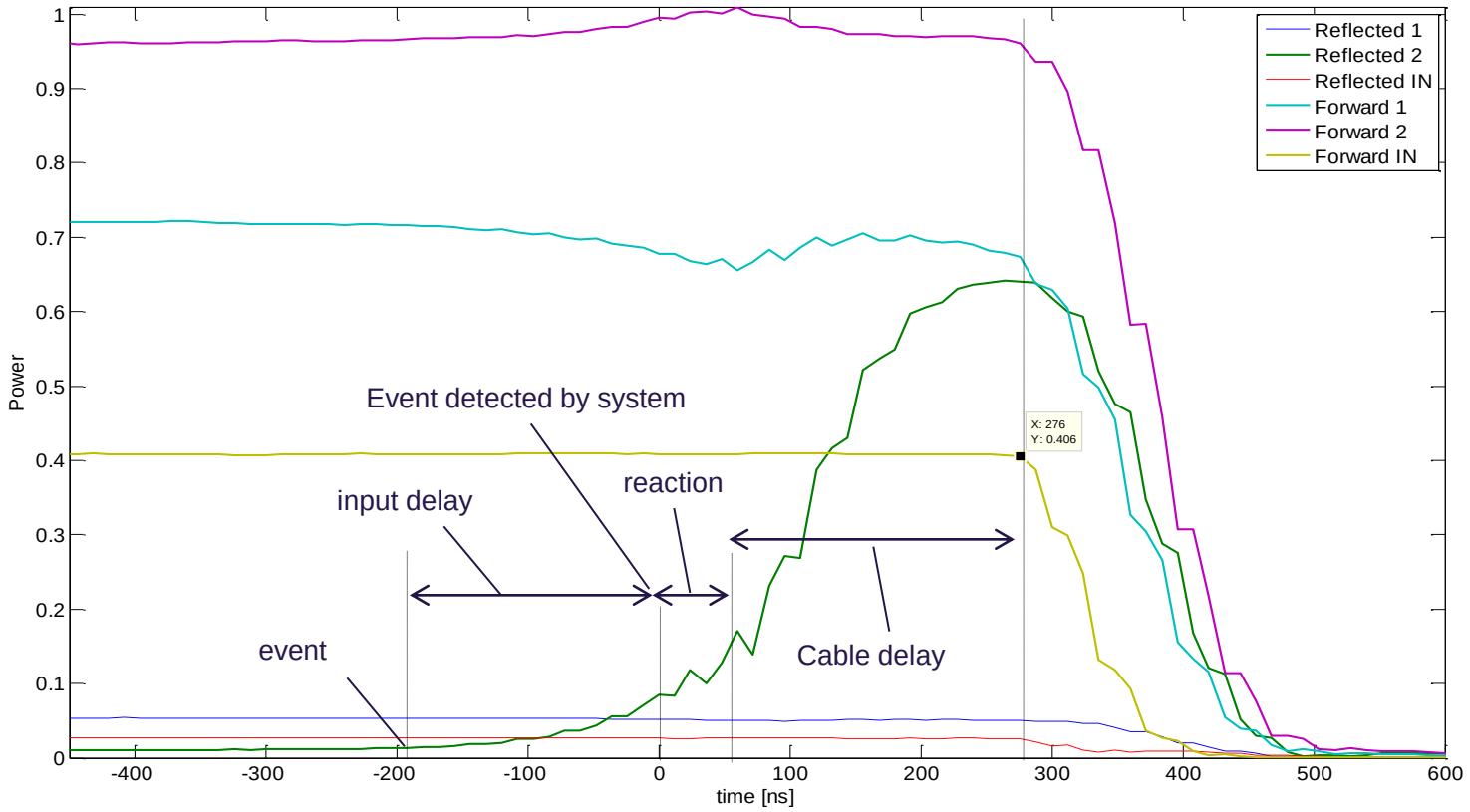
Results

To high reflection event detection (full sampling).



Real summary switching time is:

190ns input delay + 30ns system reaction + 250 ns cable delay = 470ns

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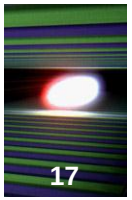
Conclusion



- The necessary software and hardware for KLM system was developed, the transfer matrix of RF system including the klystron, RF amplifier and directions couplers was measured.
- KLM system based on SIMCON board, since October 2010 is in operation on Klystrons Test Stand.
- The reaction time on the RF events is about 250 ns.
- One of the possible recovery procedure after RF events was tested.

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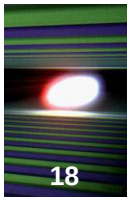
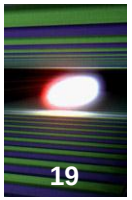
Future plans



- Implementation on xTCA (part of software already done)
  - Installation at Klystron test stand;
- Installation at FLASH, to verify event detection and then enable protection functions;
- Add protection and measurements of
  - X ray sensors
  - Light and sound sensors
- Improve calibration method
- Develop new hardware for xTCA, more suitable for fast interlock system.



Thank you for attention