KLYSTRON MEASUREMENT AND PROTECTION SYSTEM FOR XFEL ON THE MTCA.4 ARCHITECTURE

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HELMHOLTZ ASSOCIATION

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DESY

Outline

- Introduction
- System overview
- Protection and measurement functions
- Installation at XFEL
- Installation at Klystron test stand
- Event detection
- Conclusion

Introduction

- The klystron is a specialized linear-beam vacuum tub

  XFEL:

  - Multi Beam Klystron providing up to 10 MW, 10Hz, 1.7 ms HV and 1.5 ms RF pulse at 1.3GHz,
  - 27 RF stations

  Very expensive device!

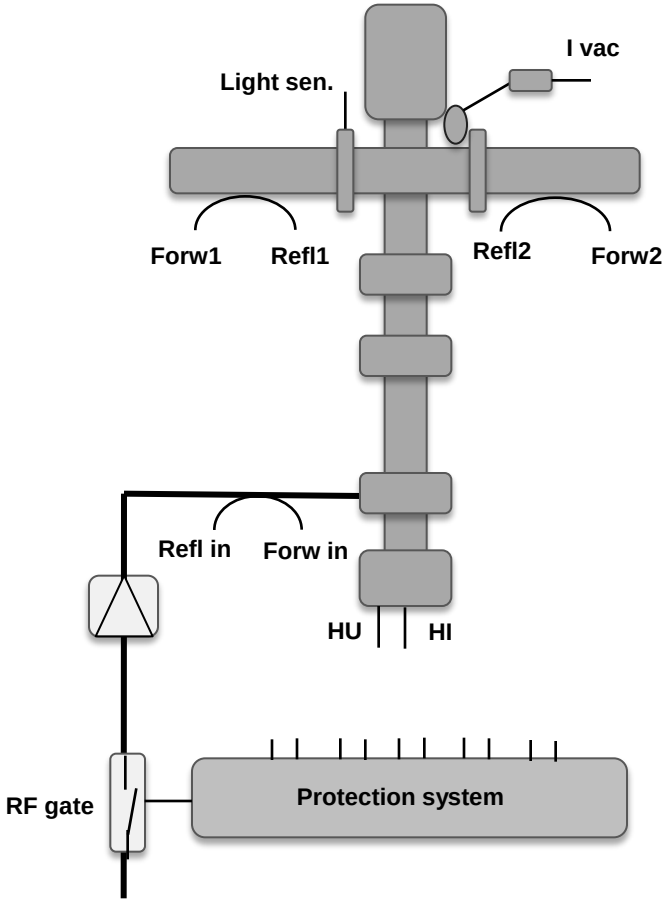
- Klystrons undergoing frequent failures and have limited lifetime.
- Lifetime of the tube should be in excess of 60,000 hours,
  - Not easy to achive,
  - Dispenser cathode with beam loading of 2.A/cm^2 can provide average lifetimes of 145,000 hours!
- There is a few factors which can reduce lifetime of the tube.

Introduction

- Destructive factors:
  - Bad vacuum: indicates ions current, RF and HV breakdown;
  - RF breakdowns: destructs cavity surface and can pollute RF window that increases reflected power and probability of RF breakdown;
  - Gun arc: destructs the cathode and anode surface and can pollute HV insulator and cathode
  - Work in deep saturation: beam loss, bad vacuum.
  - High RF reflections: beam loses
- To prevent occurrence of the destructive factors the fast interlock is required.
  - System should detect exceptional events and reacts as fast as possible by switching off driving signal;
- Fast interlock and measurement system was developed in DESY for XFEL. It is called Klystron Lifetime Management system (KLM).
  - Currently tested at klystron test stand

System overview

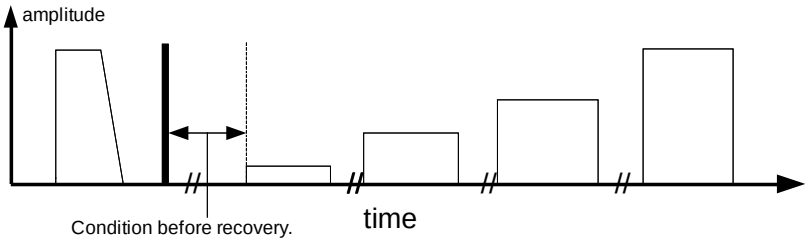
- Klystron signals:
  - 6 RF signal from out and in couplers;
  - 2 DC signals form connection module
  - 1 signal from vacuum pump
  - 1 signal from light sensors
- Measurement of parameters:
  - reflected power and phase at first klystron arm;
  - reflected power and phase at second klystron arm;
  - reflected power and phase at klystron input;
  - forward power and phase at klystron input;
  - forward power and phase at first klystron arm;
  - forward power and phase at second klystron arm;
  - klystron high voltage;
  - klystron high current;
  - klystron vacuum pump current;
  - light sensors votage;
- Protection:
  - Switch off RF gate

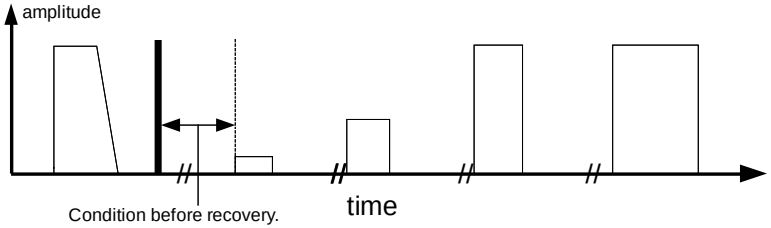


System overview

- Event detection functions:
  - Correspondence of input and output power: RF breakdown inside tube detection;
  - Reflection power check: detects to high reflection power, RF breakdown detection;
  - Too high input power: saturation check;
  - High voltage breakdown;
  - Bad vacuum detection;
  - Gun arc detection;
  - RF breakdown in waveguide distributing system near klystron output windows;

- Recovery modes:
  - Run after event detection,
  - 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.

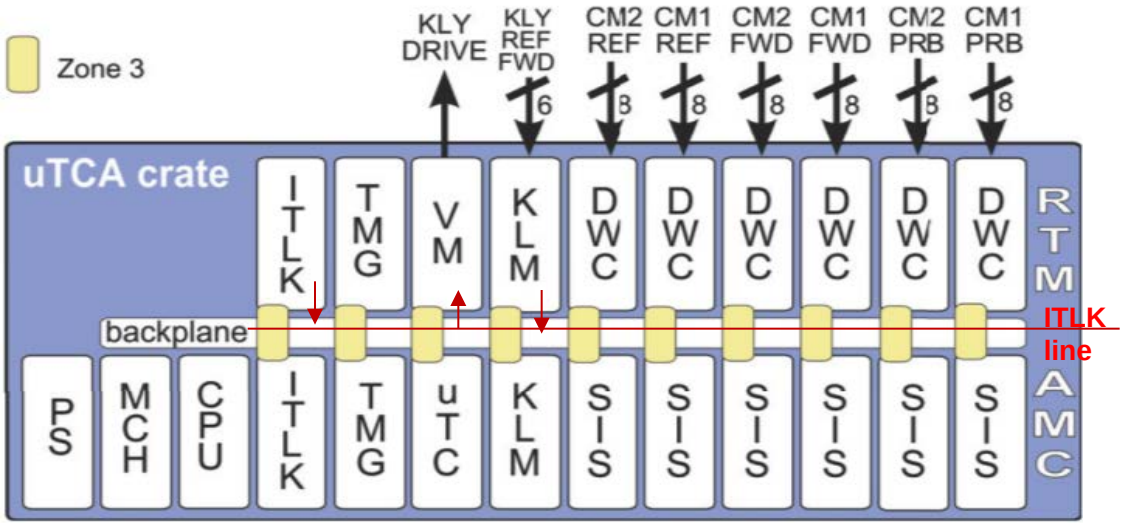




XFEL installation

- For the XFEL the Mi-cro TCA technology (MTCA.4 or xTCA) was chosen to support LLRF system
- Klystron lifetime management (KLM) will be installed in the LLRF system crate.
- It consists of a Rear Transition Module and Advanced Mezzanine Card (RTM-AMC) pair with down-converts and digitizer board.

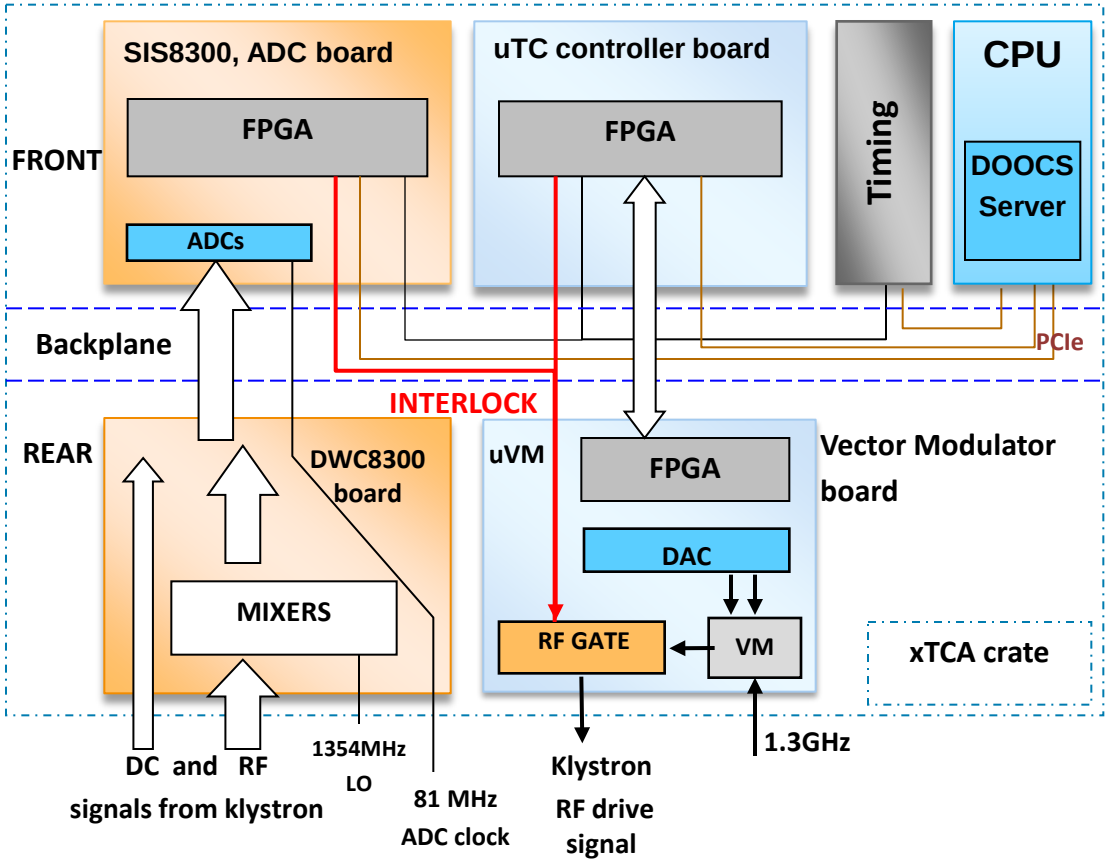
- Interlock line on backplane connected to RF gate on vector modulator board,
- KLM activate interlock signal on event and switch off RF driving signal,



Top view of the MTCA.4 boards distribution

Klystron test stand

- At test stand klystrons are tested before they will be installed in tunnel,
- For installation at klystron test stand standard hardware for LLRF control system for XFEL was used,
- System components:
  - SIS8300 – AMC with FPGA AND ADC;
  - DWC8300 – RTM down converter;
  - uTC – AMC controller board;
  - uVM – vector modulator RTM;
  - TIMAMC-01 – timing module;
  - GE_ASLP11 – CPU module;
  - NMCH-CM + ELMA 12 slot crate;

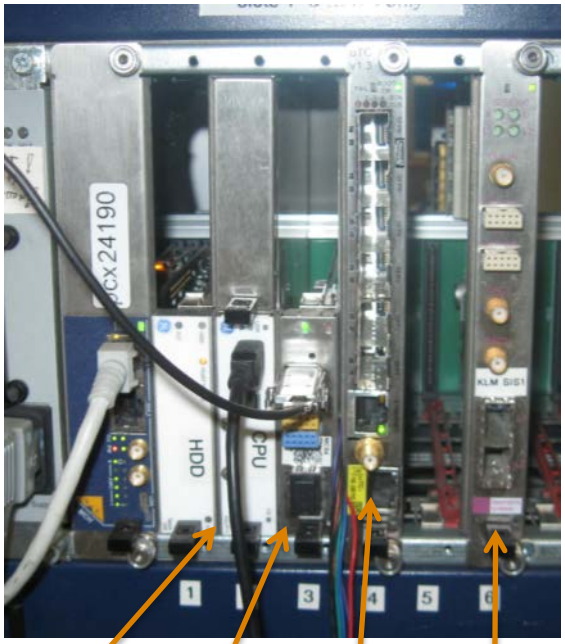


Block diagram of the KLM system

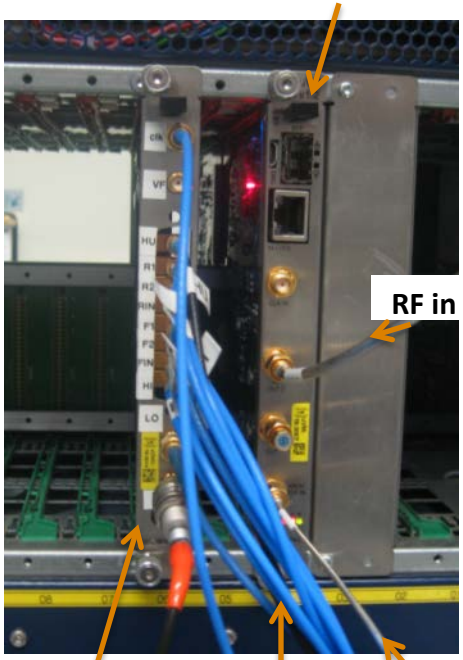
Klystron test stand

Klystron at test stand

FRONT



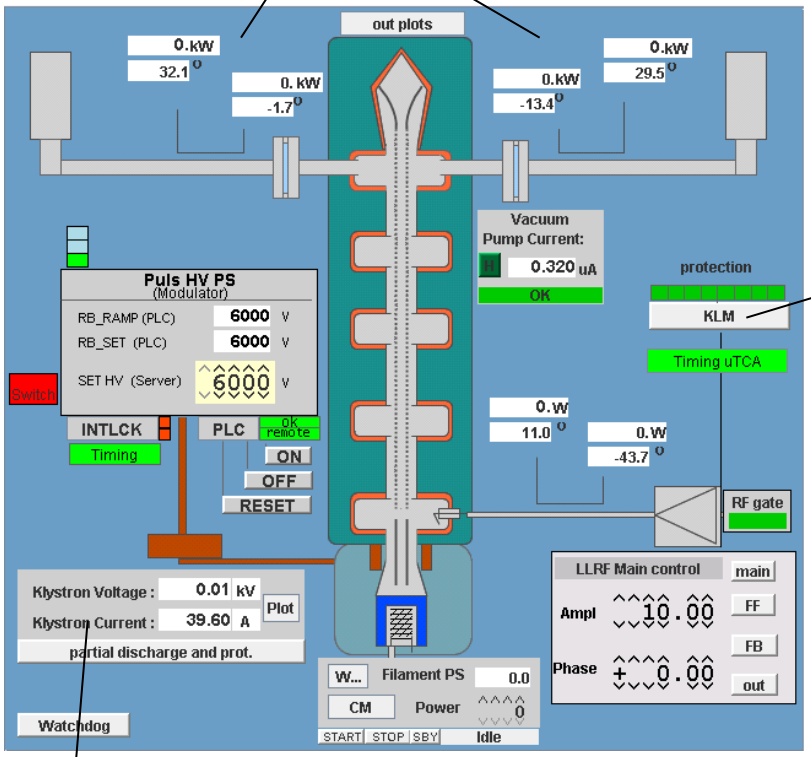
REAR



MTCA.4 crate

Control panels

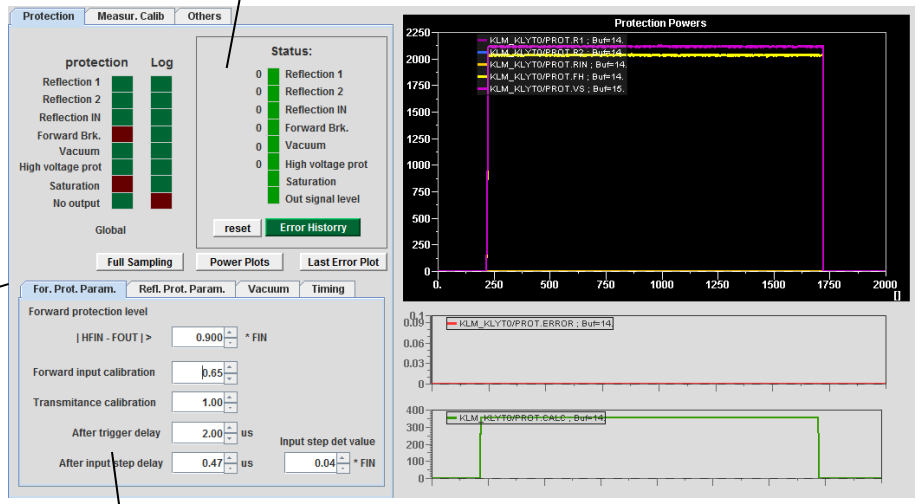
Power and phase measurement



- Main control window.

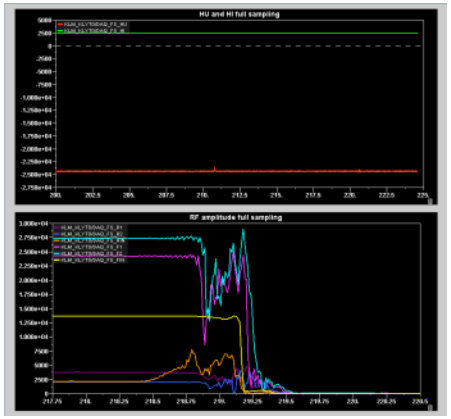
Measurement of klystron voltage and current

Protection functions and status

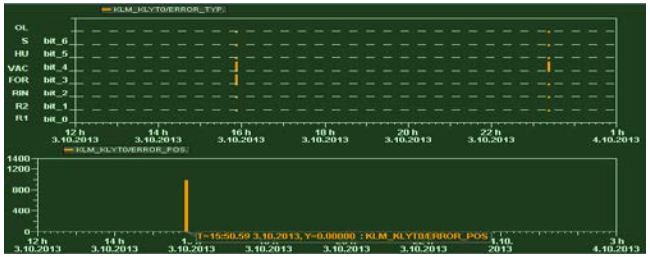


- Main protection panel

Protection parameters



- plot of detected event



- error history.

Results

- Most important parameter for fast protection system is reaction time,
- Measured reactions time:

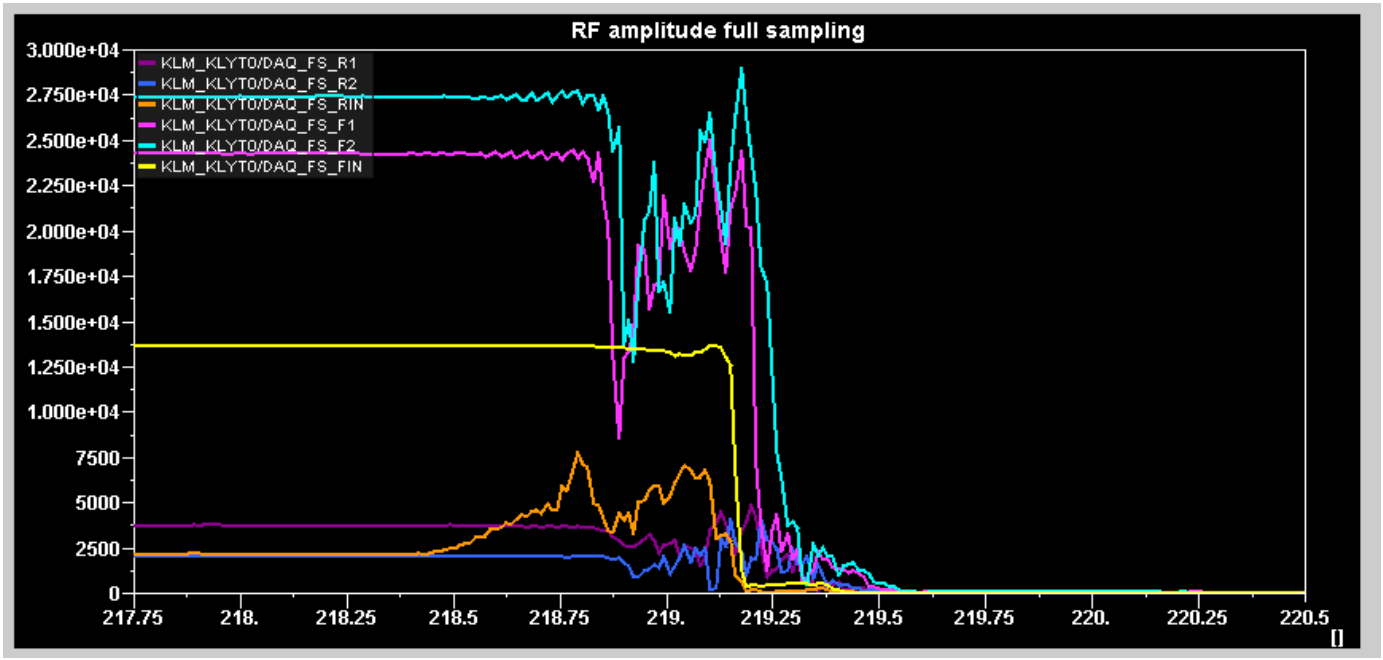
  380 ns – time from input on ADC to activate interlock line

  600 ns – all system including cables, amplifiers.

- Possible to detect several events (next slides),

Error events

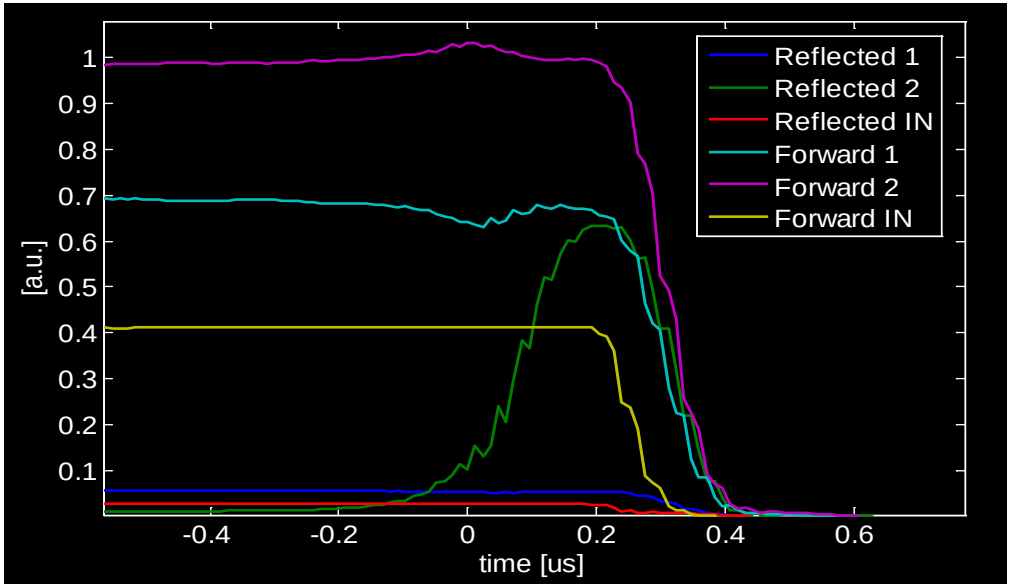
- **RF Breakdown**
  - happens inside the tube when beam loses direction,
  - beam hits cavity surface and destructs it,



Input and output klystron powers

Error events

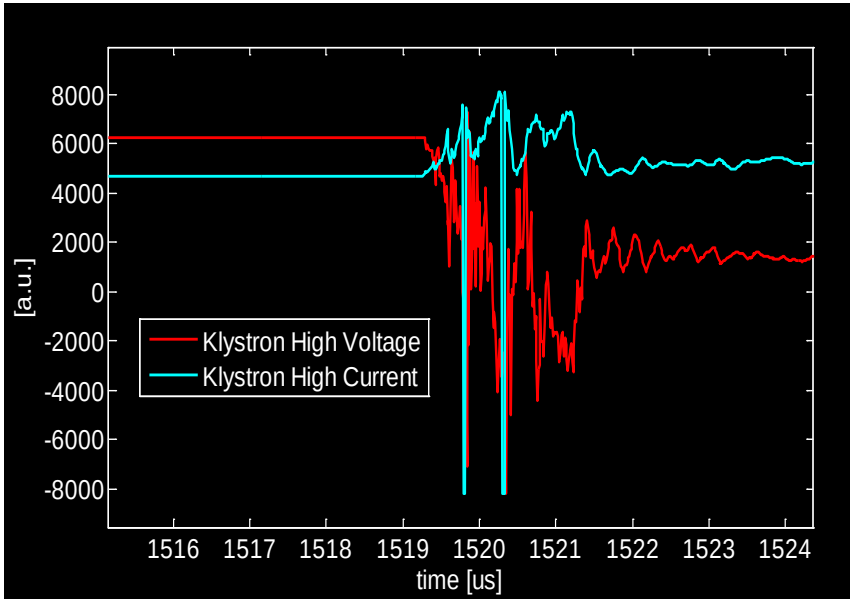
- **Too high Reflection**
  - high power reflection at out is caused by RF breakdown somewhere in waveguide,
  - redistributes the voltage in the klystron output cavity and is a reason of breakdown in cavity,



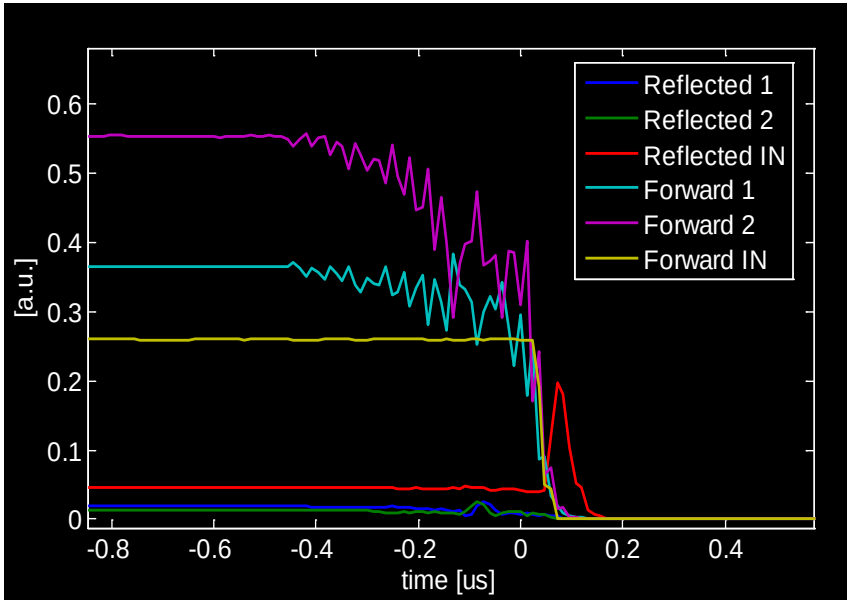
Input and output klystron powers

Error events

- **High voltage breakdown**
  - High voltage breakdown happens in the gun area of klystron
  - causes power generation loses, decrease quality of vacuum, destructs cathode and damage the anode surface



Klystron high current and high voltage



Input and output klystron powers

Conclusion

- The necessary software and hardware for klystron measurement and protection was developed,
- Klystron Lifetime Management System successfully implemented on MTCA.4.
- Installed at klystron test stand on February 2013,
- Possible to detect several of exceptional events,
- Reaction time of system is around 380ns,

Thank you for attention