Other Utilities of ALBA LLRF

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Introduction

ALBA LLRF System

- ✓Based on a commercial FPGA board (Lyrtech VHS-ADAC)
- ✓Analog Front Ends for pre-processing of RF signals
- ✓Amplitude, phase and tuning loops implemented

Lyrtech Digital Board

Analog Front End

Main Feature of Digital Systems: Flexible and Fast

Other LLRF Utilities

Other Capabilities integrated in LLRF

- ✓Automated Start-up
- ✓Conditioning
  - Manual
  - Automatic
- ✓Fast Diagnostics (Fast Data Logger)
- ✓Fast Interlocks
- ✓Frequency modulation for tuning

Features implemented in the **same LLRF Hardware**

All features available in all the RF plants

Automated Start-up

After a trip LLRF set all parameters to minimum

- ✓Low RF Drive
- ✓Tuning Disable
- ✓Amplitude and Phase loops opened

Reset the interlock and switch on transmitter

LLRF detects RF presence in cavity

LLRF tune cavity before increasing power

LLRF closes Loops (Amp & Ph)

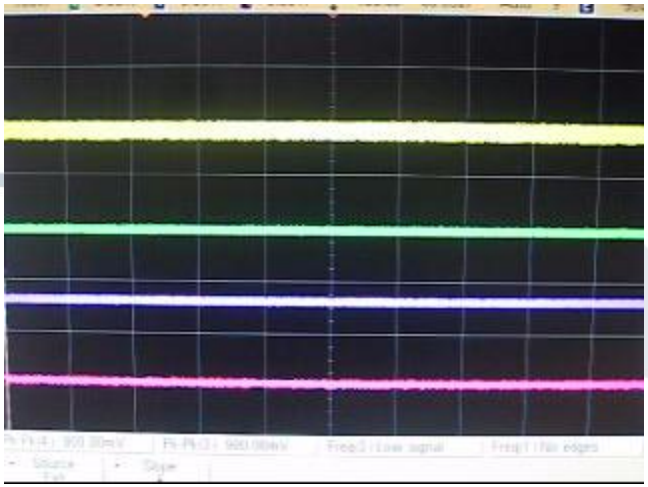
Smooth power increase

Message: Ready for beam operation

RF Power →

Tuning pulses →

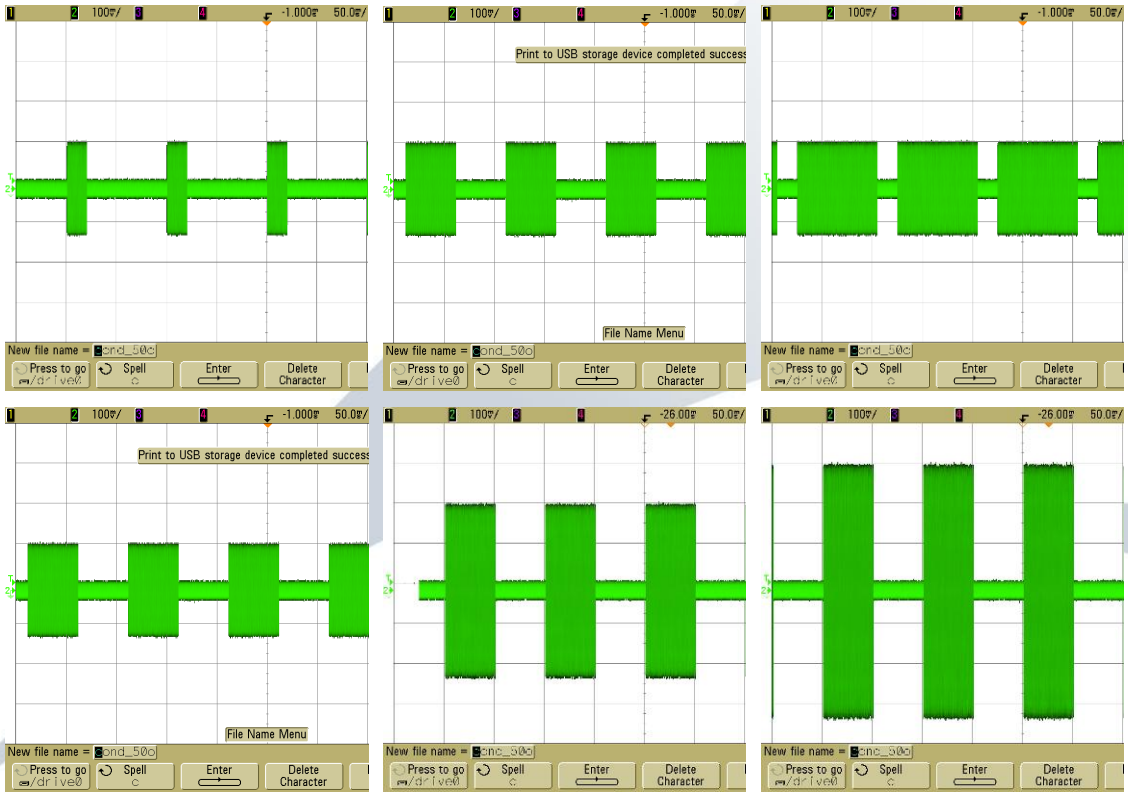
Plungers direction ↗↘



Manual Conditioning

RF Drive square modulated

- ✓Duty Cycle of pulses adjustable (1-100%)
- ✓Amplitude adjustable
- ✓Time between pulses = 100ms (10Hz)
- ✓ Tuning Loop only enable at top of the pulses

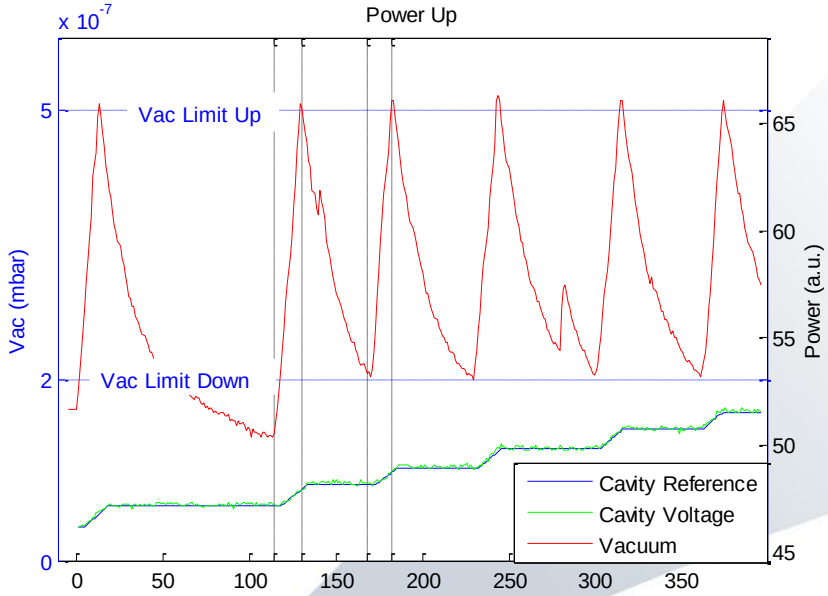


Drawbacks

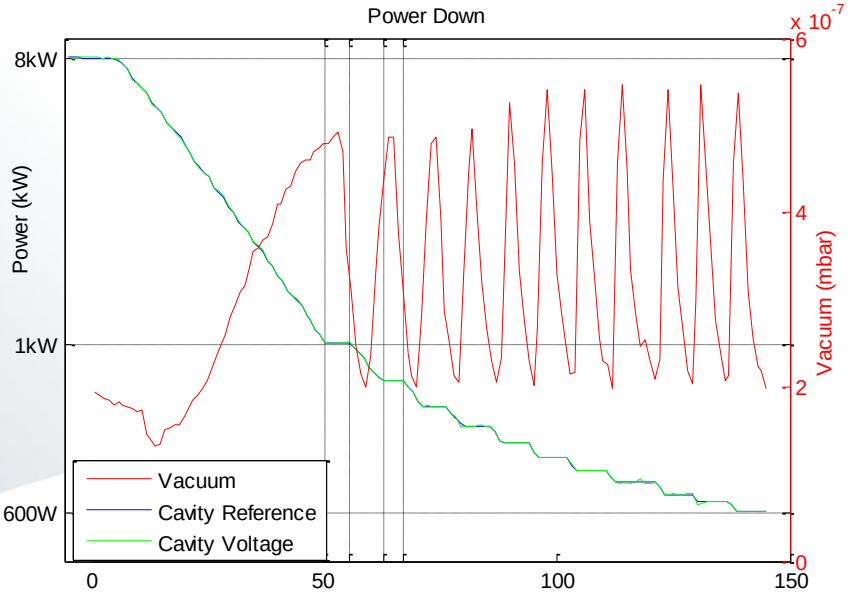
- ✓Operator needed to adjust amplitude and duty cycle
- ✓Vacuum levels not considered by LLRF → frequent interlocks

Automated Conditioning

- ✓Amplitude and duty cycle increase depending on vacuum levels
- ✓Amplitude increase rate (slope): adjusted by operator
- ✓Vacuum signal connected to LLRF



Voltage Increase rate set to 0.03mV/s



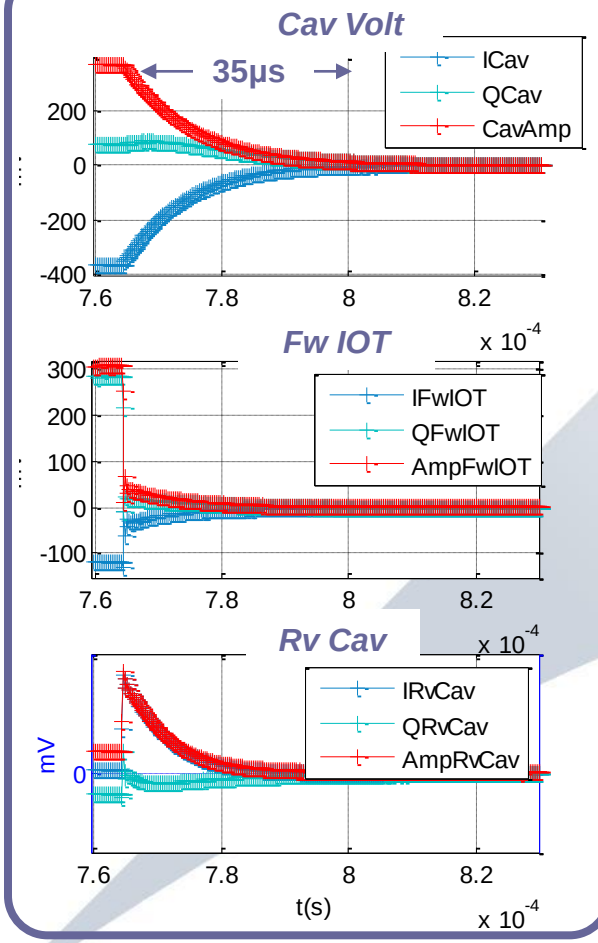
Voltage Decrease rate set to 1mV/s

- Vacuum < Limit Down → Voltage Amplitude Increases/Decreases
- Vacuum > Limit Up → Voltage Amplitude remains constant until vacuum is below limit down

RF Fast Diagnostics

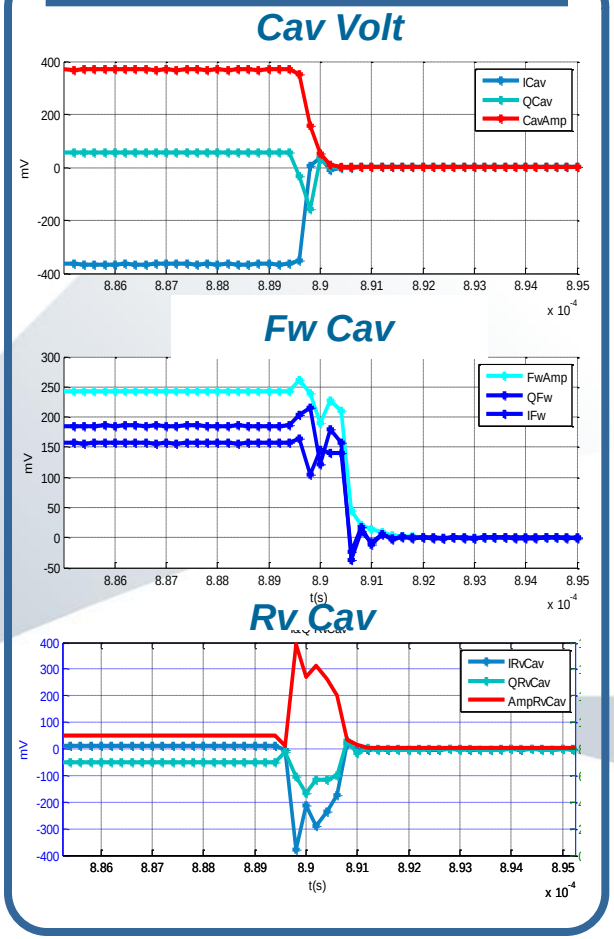
Fast Data Acquisition (MHz) for post-mortem trip analysis: Vacuum, Arcs and Ref Power)

Vacuum Trip at 47kW



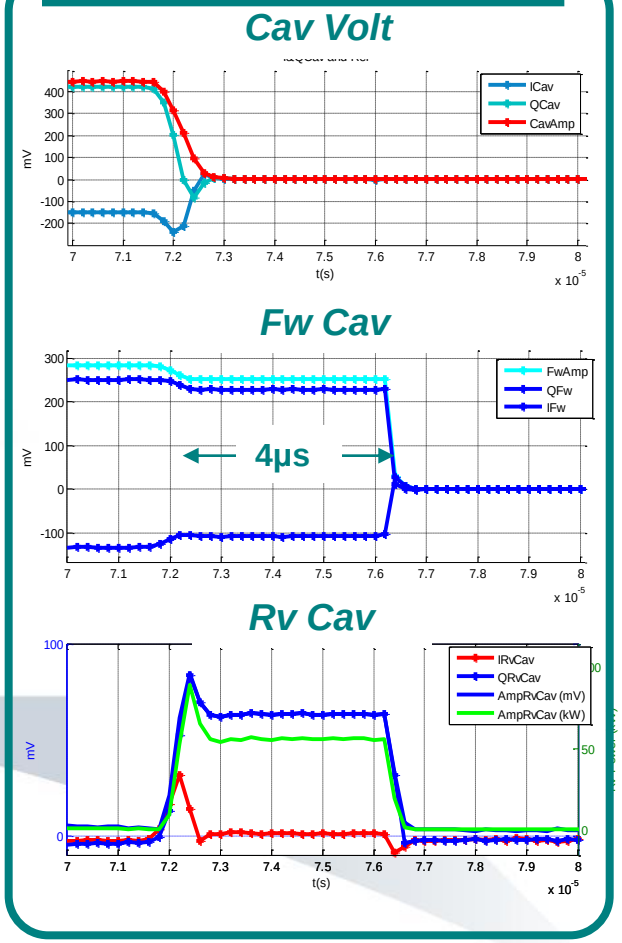
Cavity Discharged in 35 µs

Reflected Trip at 35kW



Cavity Discharged in 0.8 µs

Arc at 41kW



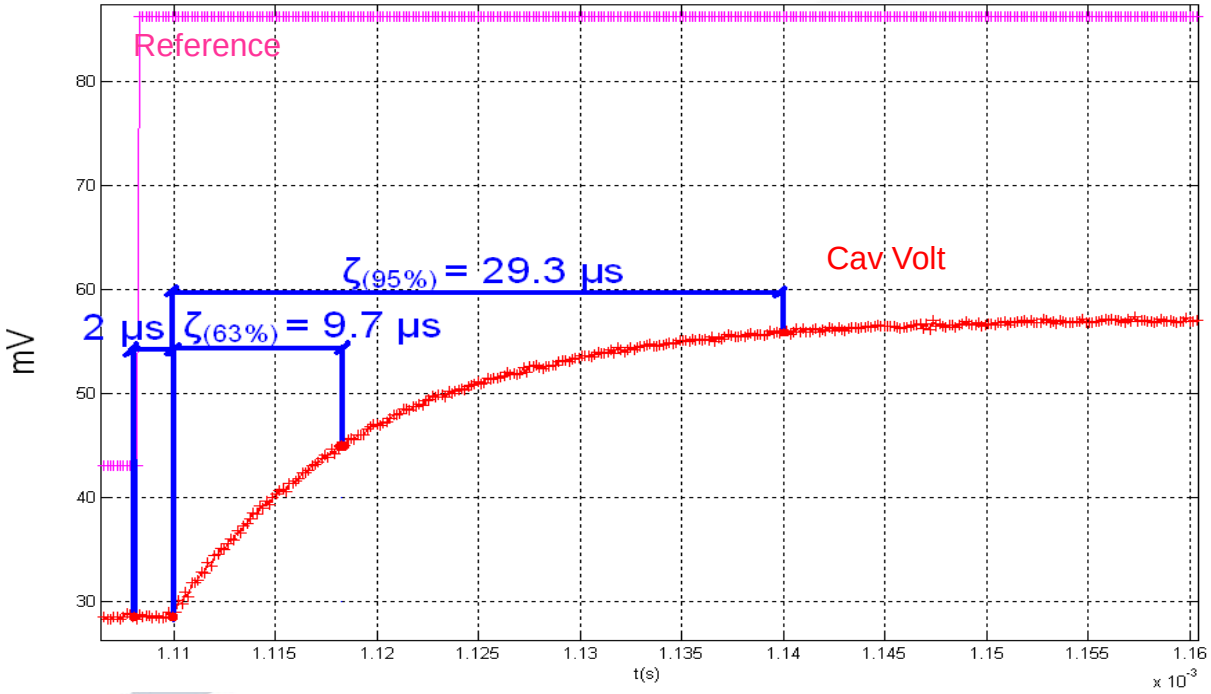
Cavity Discharged in 1.2 µs

Characterization of Cavity Transfer Function

Transfer Function: Mathematical representation of a system (model)

- ✓ to be calculated analytically
- ✓ to be measured experimentally

Experimentally: Step response in Open Loop



System Characterization
(1st Order)

- ✓ Delay = 1.93µs
- ✓ ζ (63%) = 9.7 µs
- ✓ Gain = 0.8
- ✓ Filling time = 29.3 µs

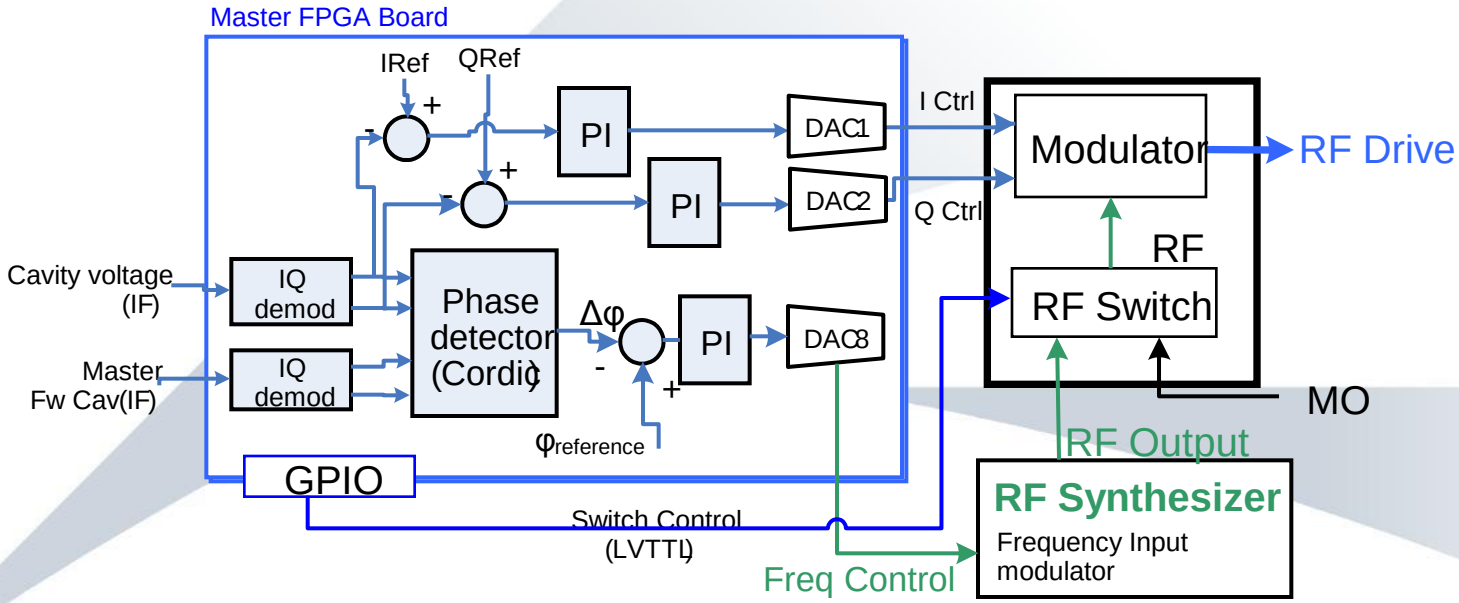
(DAMPY Cavity)

Transfer Function

$$\frac{K \cdot e^{-Ts}}{1 + \tau s} = \frac{0.8 \cdot e^{-2 \cdot 10^{-6} \cdot s}}{1 + 9.7 \cdot 10^{-6} s}$$

Frequency Tuning for Startup (RFQ Cavity)

- ✓Sometimes during startup, tuning by cooling control cannot cope with the temperature increase induced by RF power → Freq Tuning
- ✓Cavity Resonance Frequency varies freely
- ✓ RF Drive modulation to follow the resonance frequency of cavity



Fast Interlocks integrated in LLRF

Main Functionality

- ✓To cut RF Drive when an interlock happens (<10 μs)

Interlock Conditions

- ✓Reflected power above limits (RF Inputs)
- ✓Vacuum peaks (Digital Input)
- ✓Arcs (Digital Input)
- ✓External Input from general control system

Other Fast Interlock Actions

- ✓Circular buffer trigger
- ✓Loops Disable
- ✓DACs Disable
- ✓Communication to general control system