Digital Low Level RF Control System for the DESY TTF VUV-FEL Linac

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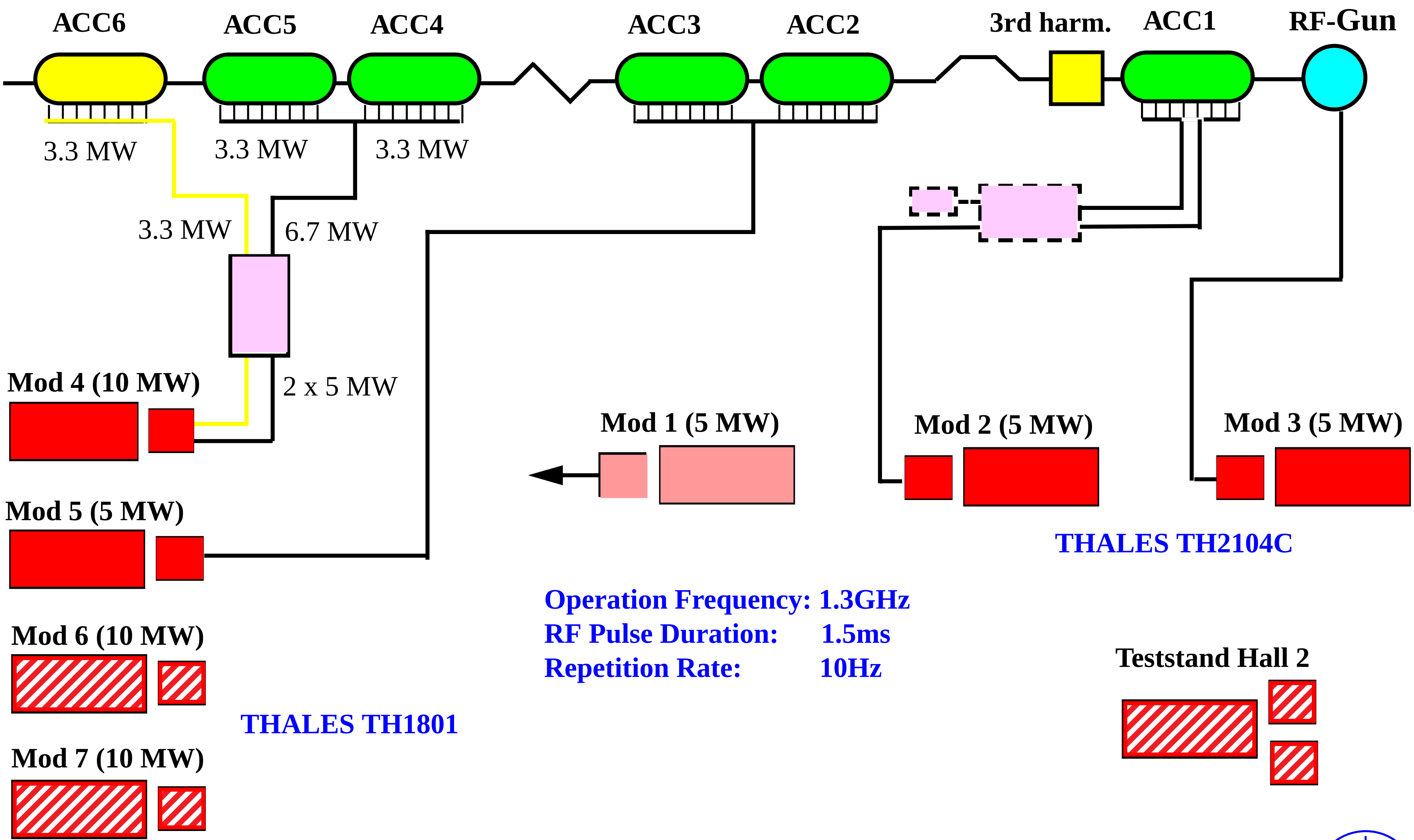
Outline

- Overview of RF System
- Requirements for RF Control
- Components of Digital Control System
  - Hardware
  - Software
- Conclusions

VUV-FEL RF System Diagram



Operation Frequency: 1.3GHz
RF Pulse Duration: 1.5ms
Repetition Rate: 10Hz

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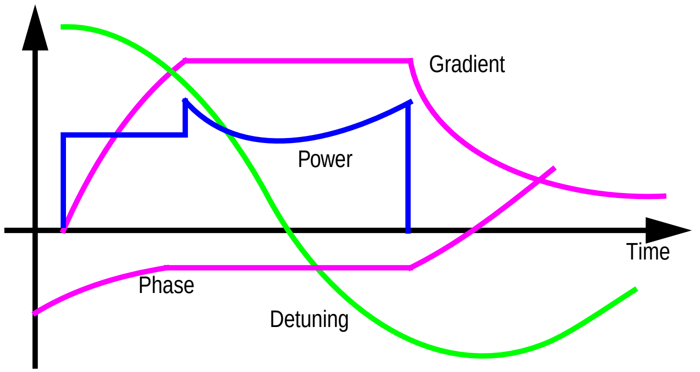
RF Control Requirements

- Amplitude and Phase Stability:

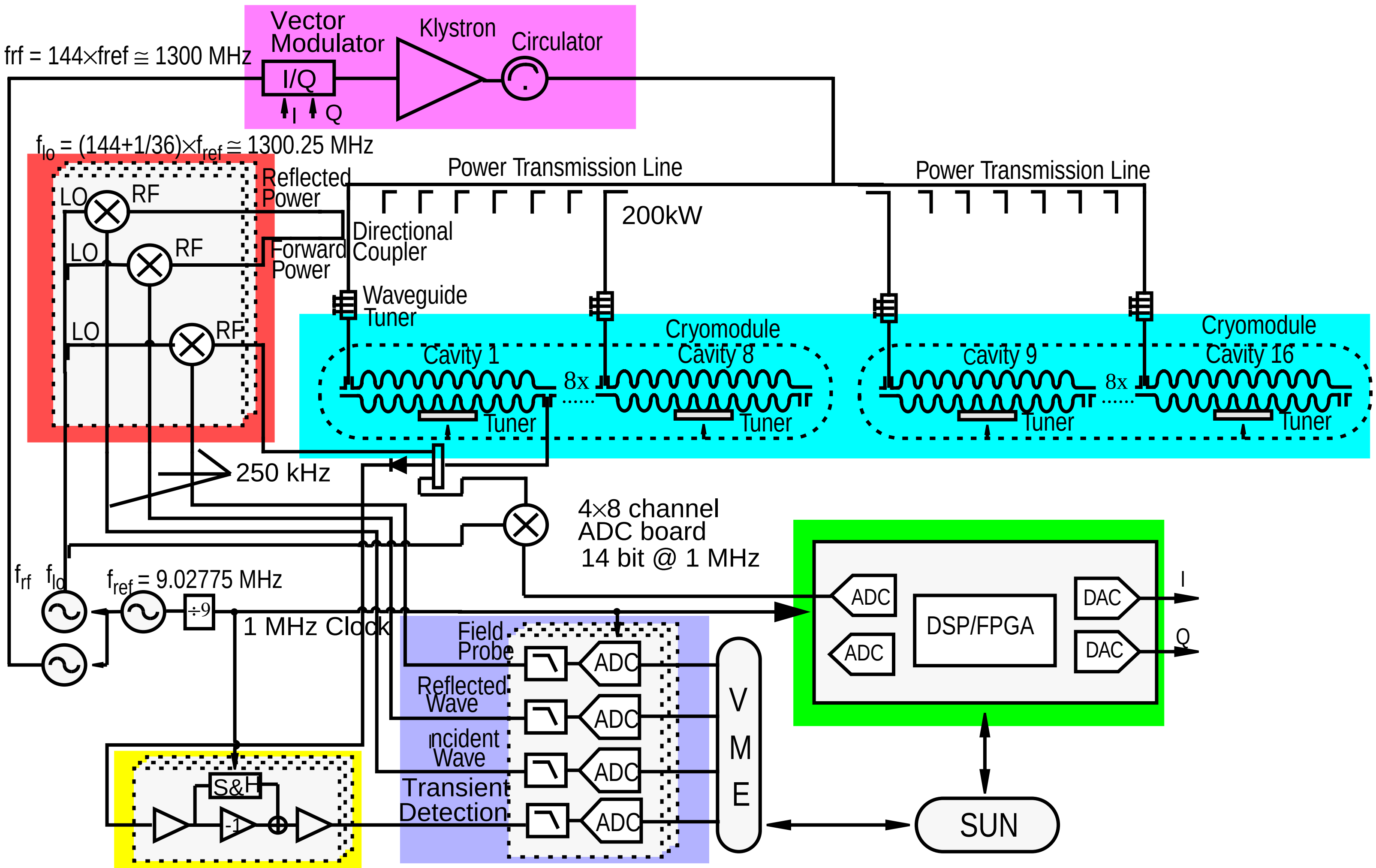
- $\sigma_A / A < 10^{-4}$ amplitude
- $\sigma_\varphi < 0.1°$ for phase (fast fluctuations)



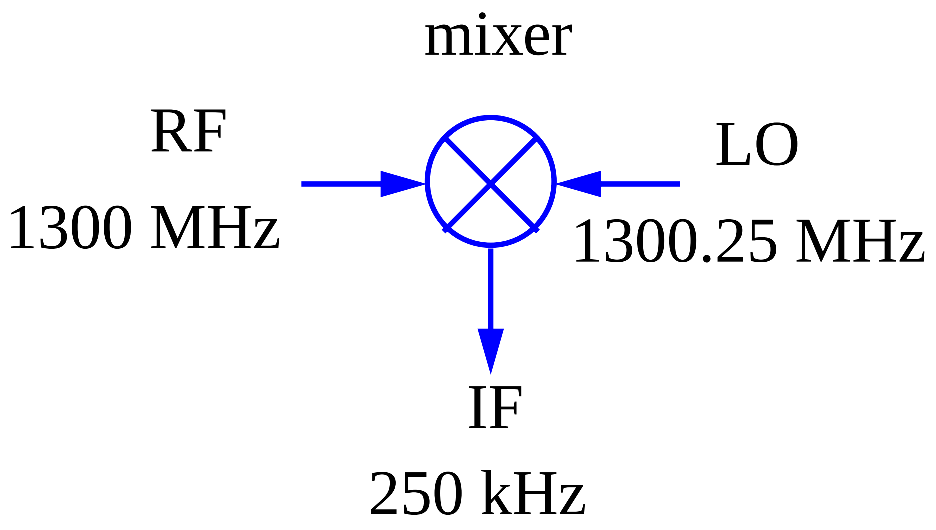
- Other requirements:

- ACC1: cav. 1-4 at 12 MV/m, cav. 5-8 at 20 MV/m phase of accelerating field -10.8 deg.
- 3rd harmonic cavity at 14 MV/m at 183 deg.
- S-Band cavity at 2856 MHz phase stability < 1 deg.
- RF Gun operation without field probe. rep. rate, pulse length and power must be variable.

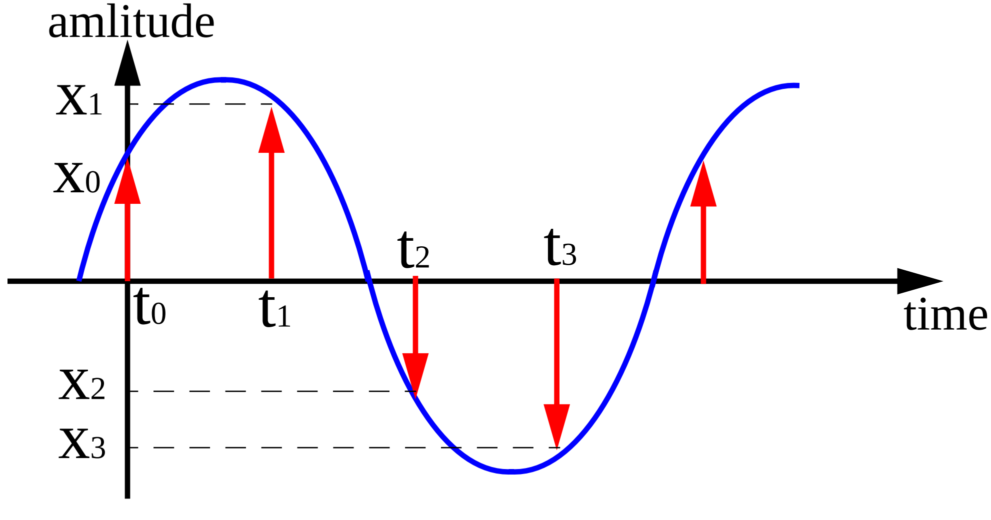
Schematic of the Digital RF System



Digital I/O Detection

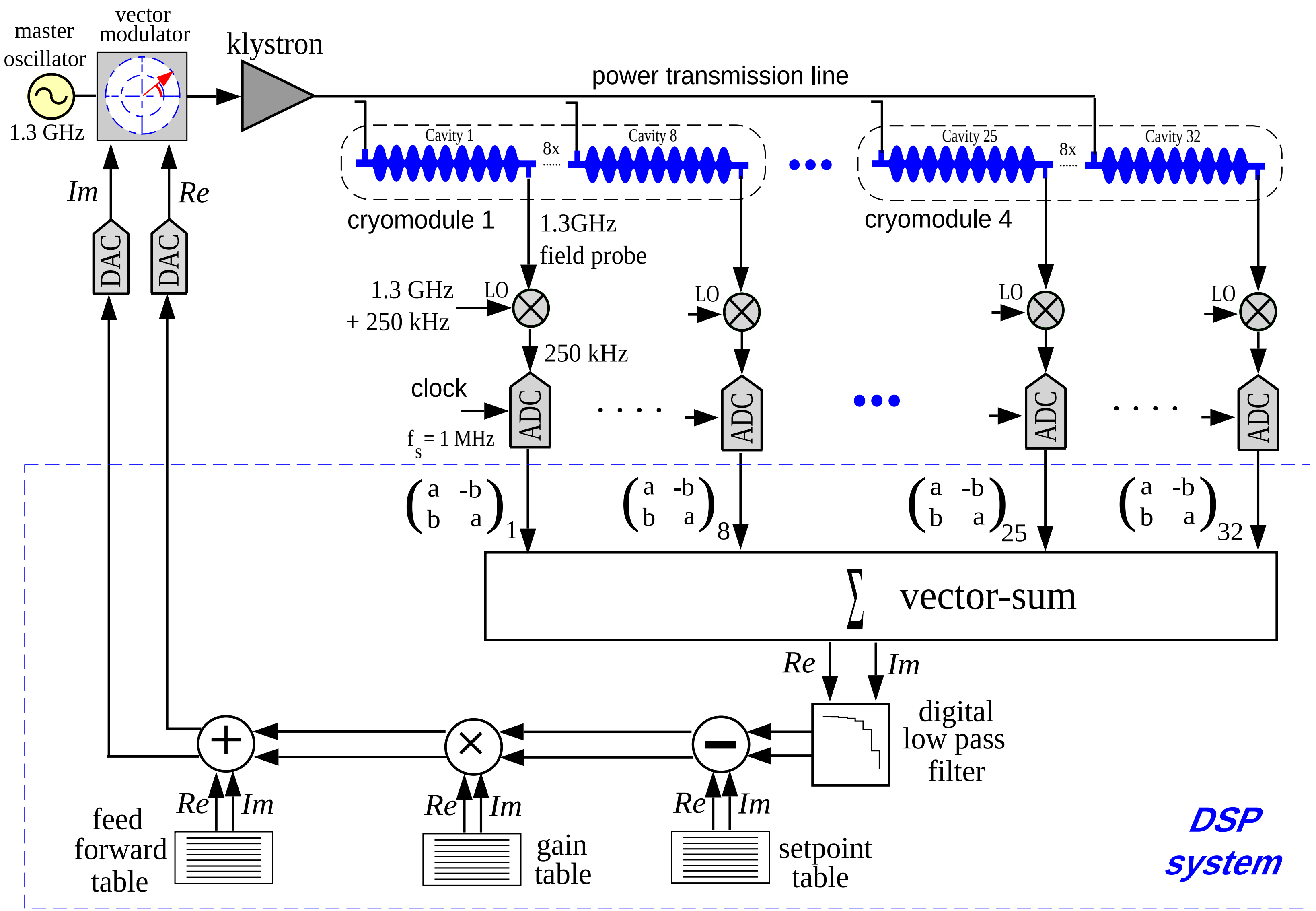


- downconversion of cavity field to IF frequency at 250 kHz
- complete phase and amplitude information of the accelerating field is preserved.



- sample IF signal at 1MHz rate
- subsequent samples describe real and imaginary component of the cavity field.

Control Algorithm



Digital Feedback Hardware

- DSP System
- New hardware, faster DSPs (C67), input channels for the control of 8/16/24 cavities
- 8 channel ADC board
- 8 channel DAC board, gigalink interface between boards

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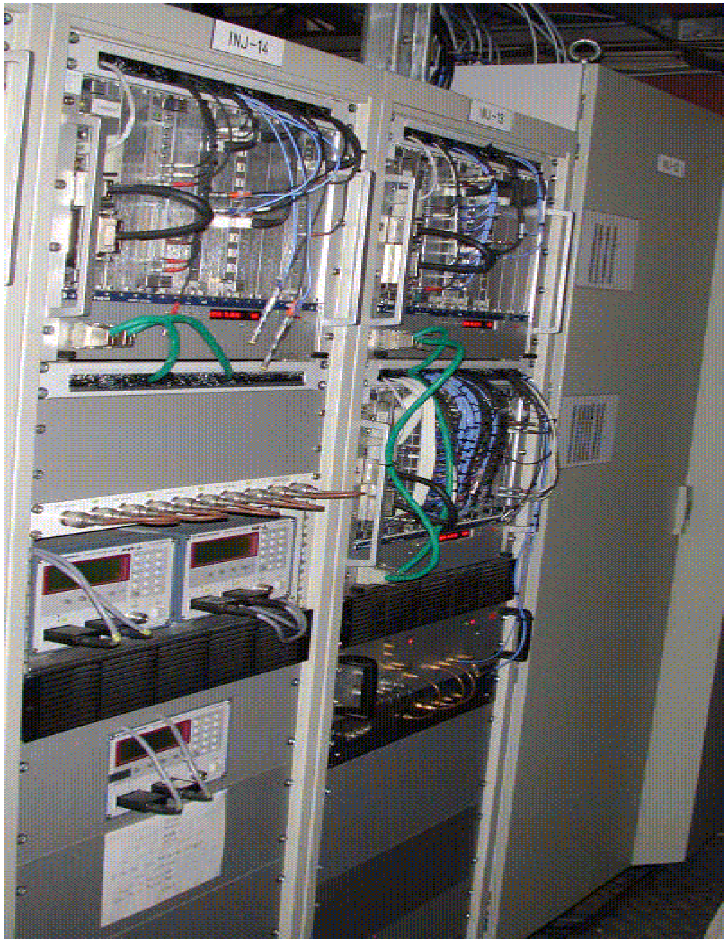
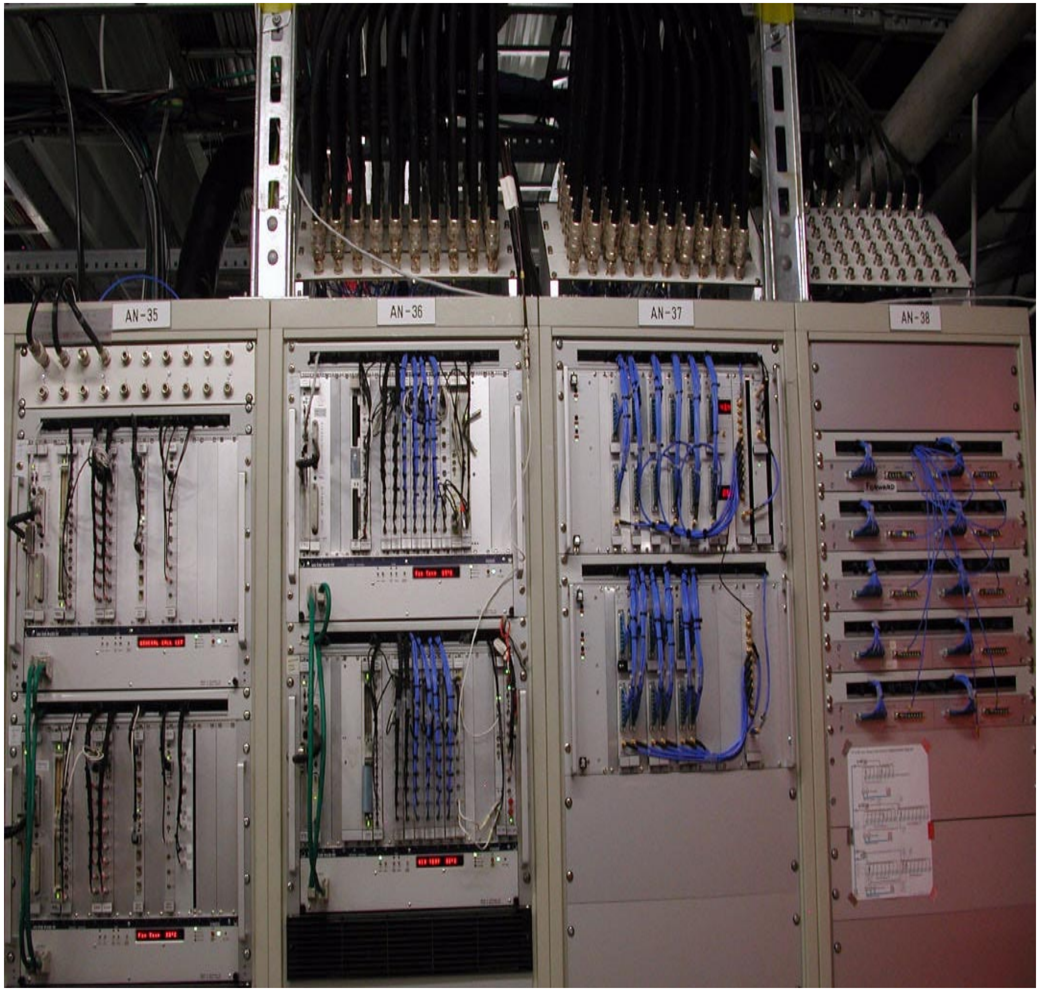
Digital Feedback Hardware (3)

Gun and ACC1



ACC2, ACC3, ACC4 & ACC5



Digital Feedback Software

- DSP System

- Exception detection and handling

- DOOCS DSP Server

- Parameter based operation, tables for setpoint, feedback gain and feedforward calculated by server

- DOOCS Finite State Machine Server

- Automated operation, Simple operator interface

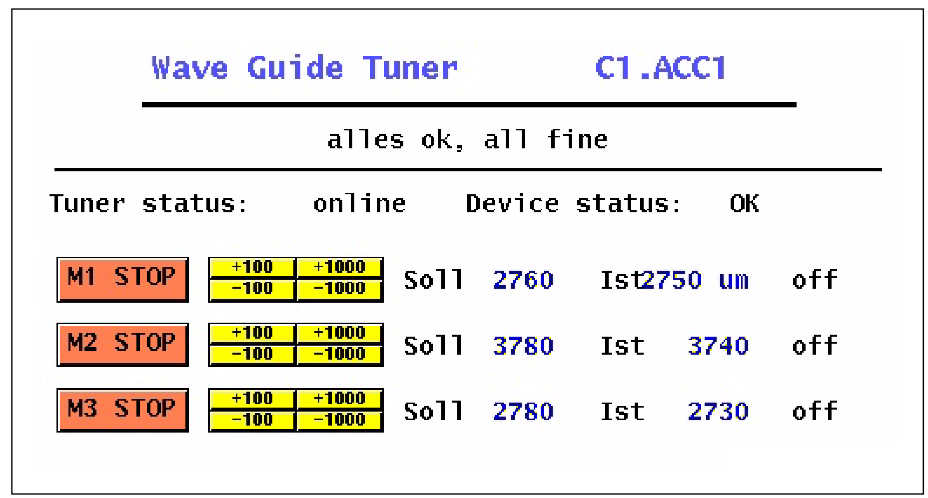
- Application tools

- Adaptive feedforward, Beam phase measurement, Loaded Q and cavity detuning measurement...

Cavity Loaded Q and Phase Adjustment

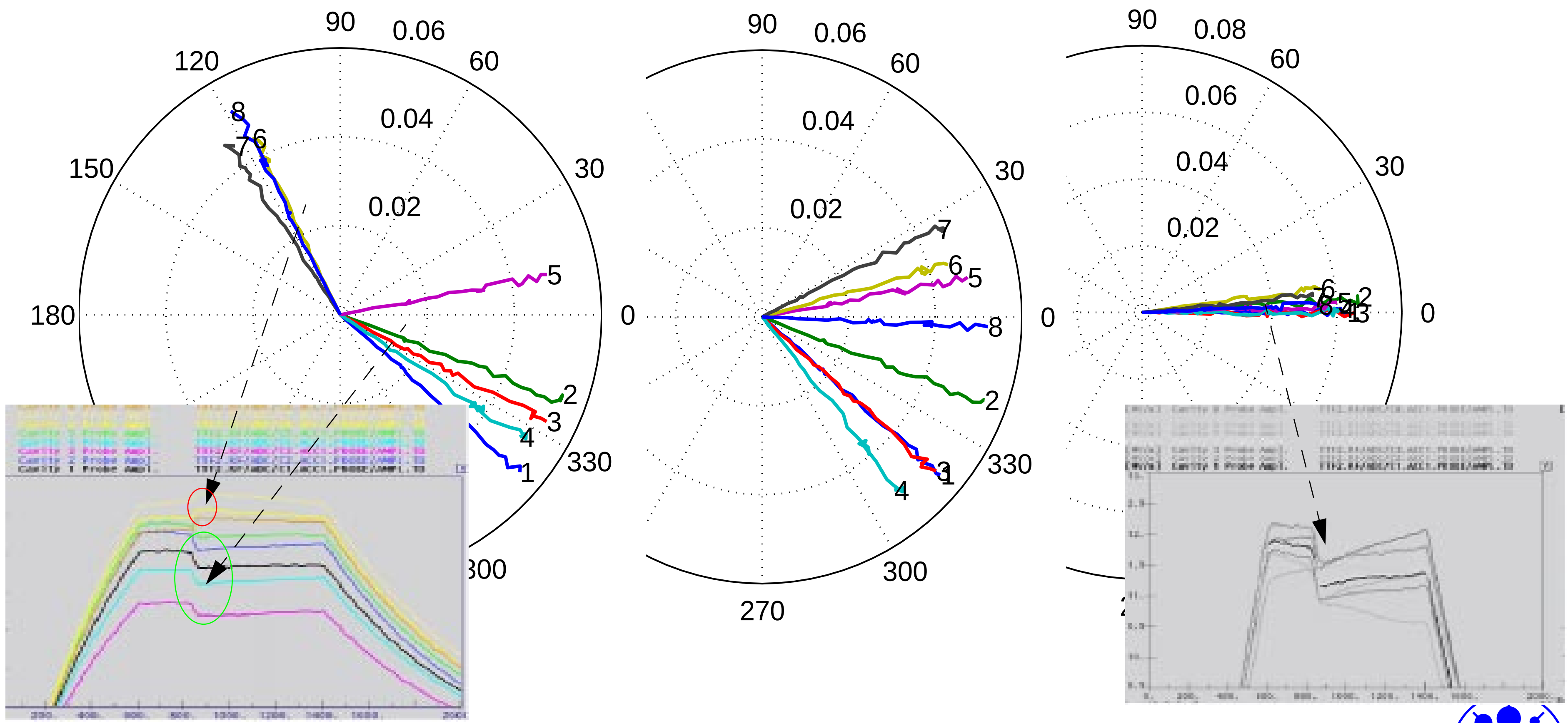
Motorized three stub waveguide tuners used to adjust phases and loaded Q for all cavities

- Improvement from ±30° to ±3°



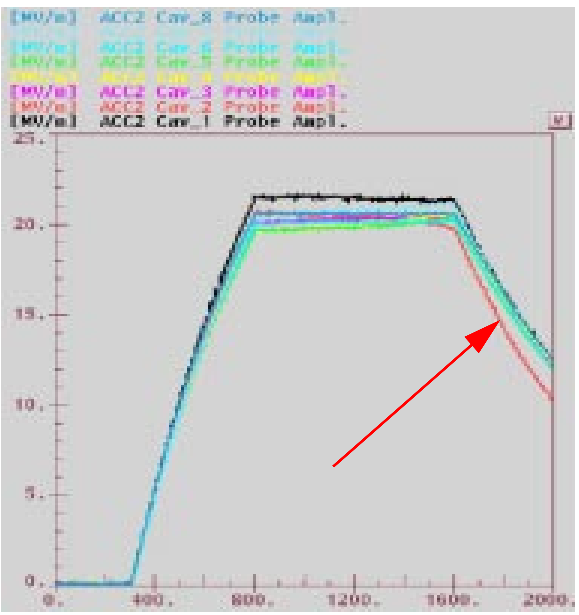
Beam Based Calibration

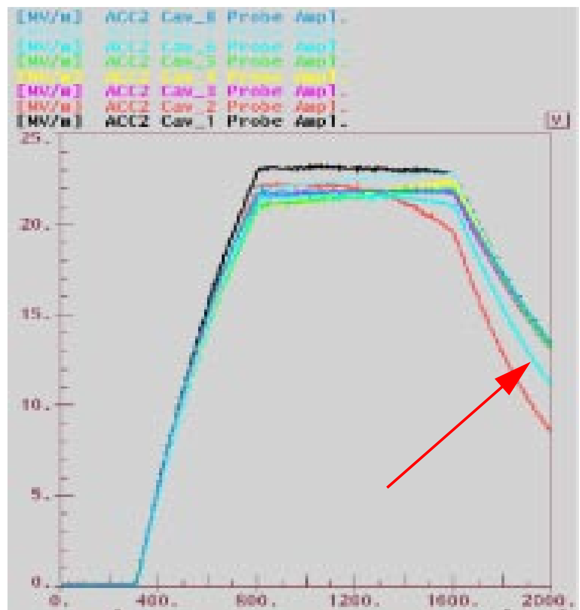
- Good beam required to get sufficient signal (8nC, 30µs, 15MV/m)
- Preliminary calibration (to 10%)
- Gradient calibration (to 3-5%)

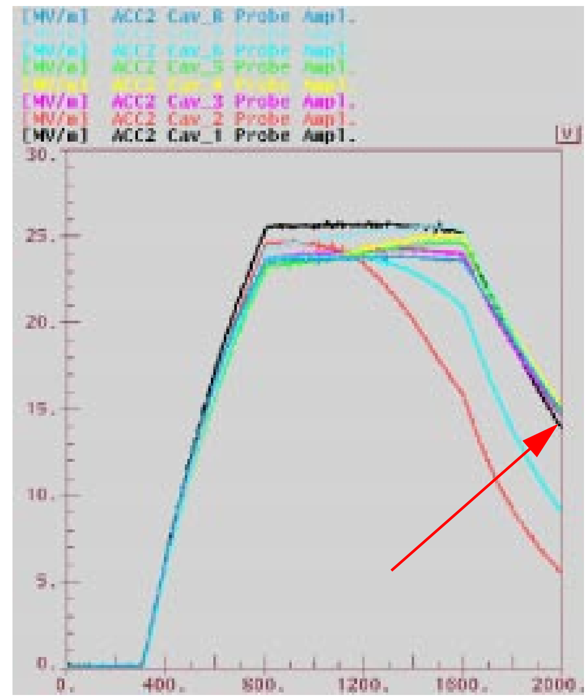


Exception Handling

- Cavity quench detection mechanism (algorithms)
- Exception handling procedure







Module 1 at high gradient

1-st quench in Cavity 2
Eacc=19[MV/m]

2-nd quench in Cavity 6
Eacc=21[MV/m]

3-rd quench in Cavity 1
Eacc=24[MV/m]

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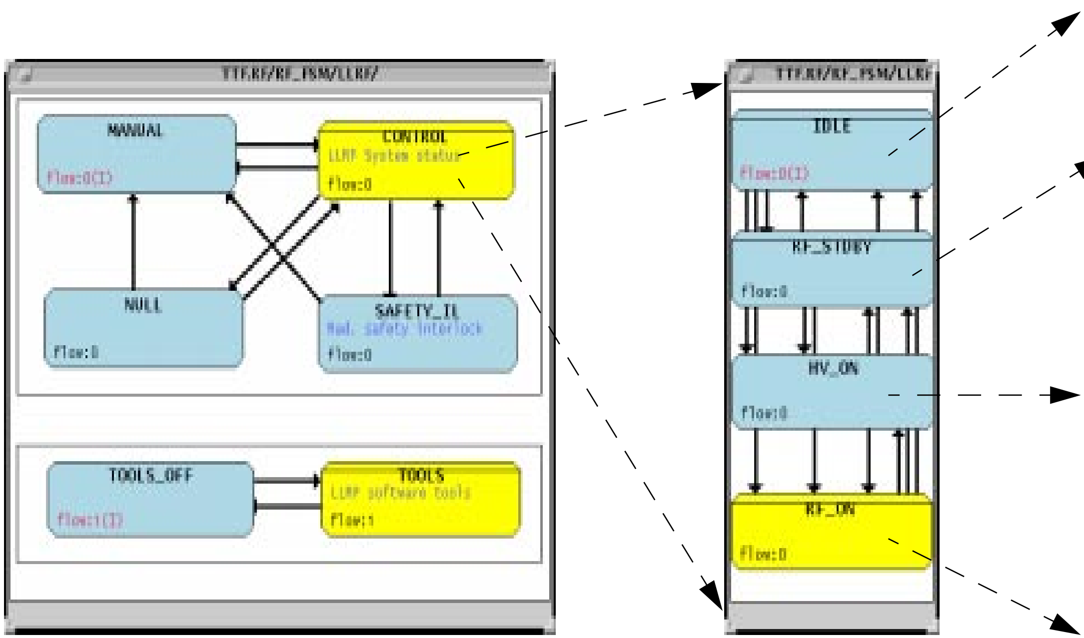
Automation of RF Operation

- High degree automation of accelerator operation
- Reduce workload of operators
- Maximize availability of accelerator



Graphical representation of logical dependencies

IDLE

Start-up procedure

RF_STDBY

Check/reset interlocks,

Find source, check limits...

HV_ON

High voltage is applied,

RF is not permitted

RF_ON

Adjust feedback loop,

Optimize beam parameters

Conclusions

- A digital RF control system has been developed to control the vector-sum of the accelerating field of group of superconducting cavities powered by a single klystron
- The RF control system is realized as a driven feedback system and has proven that the phase and amplitude stability require-ments can be meet even in the case of control of the vector-sum of multiple cavities
- First lasing at a wave length of 30nm was observed beginning of this year with feedback only
- Automation of RF operation under development
- Next generation RF control based on FPGA under development

Acknowledgements

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