Requirements for LLRF Control

LLRF Lecture Part1

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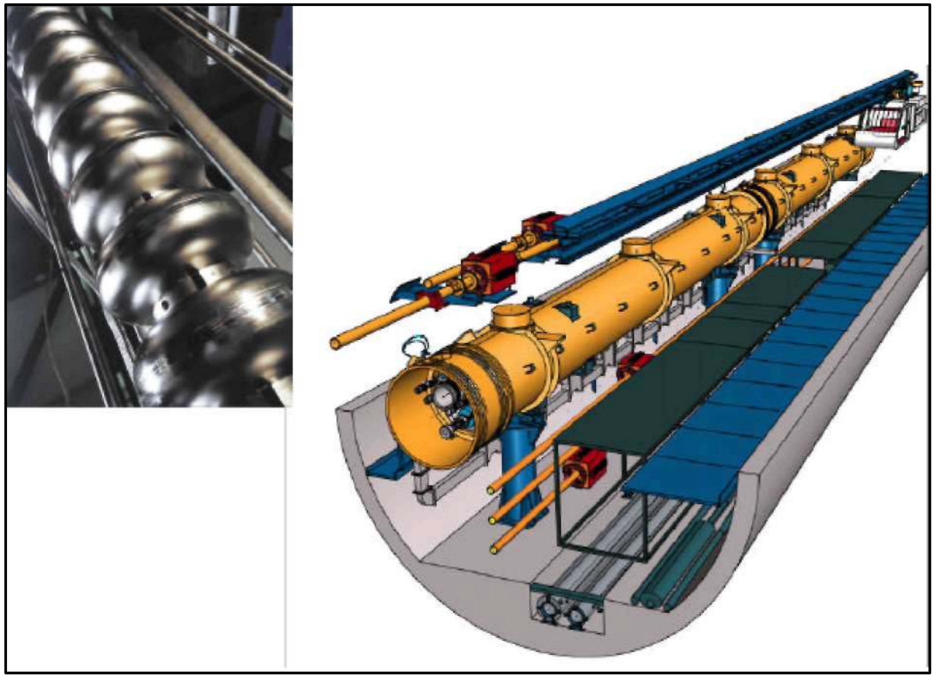
ITER / DESY

Requirements for ILC

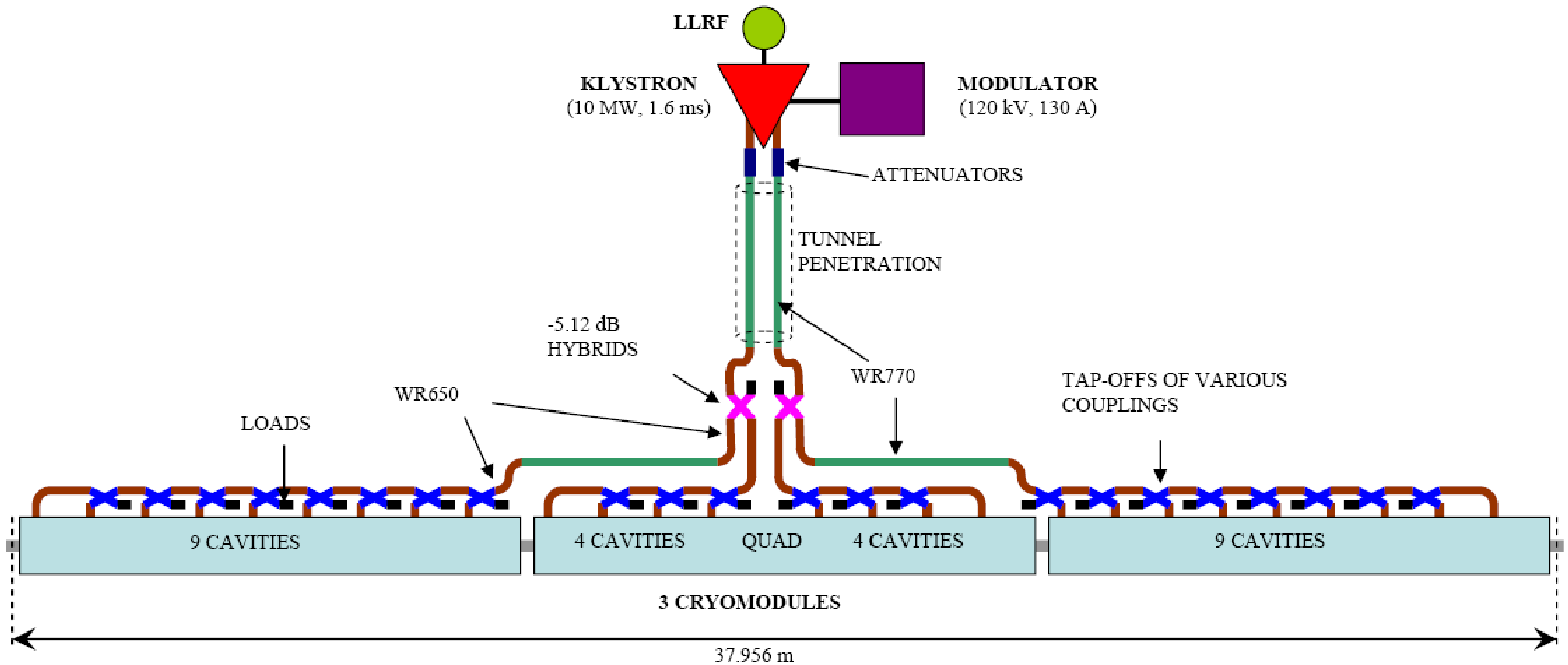
- CM energy: 500 GeV. Range 200 - 500 MeV. Upgradeability to 800 GeV
- Luminosity and reliability of the machine should allow $L_{eq} = 500\ \mathrm{fb}^{-1}$ during first four years
- Energy scans between 200 GeV and 500 GeV. Energy change should take less than 10% of data taking time.
- Beam energy stability and precision should be below the tenth of percent level

RF Systems for ILC

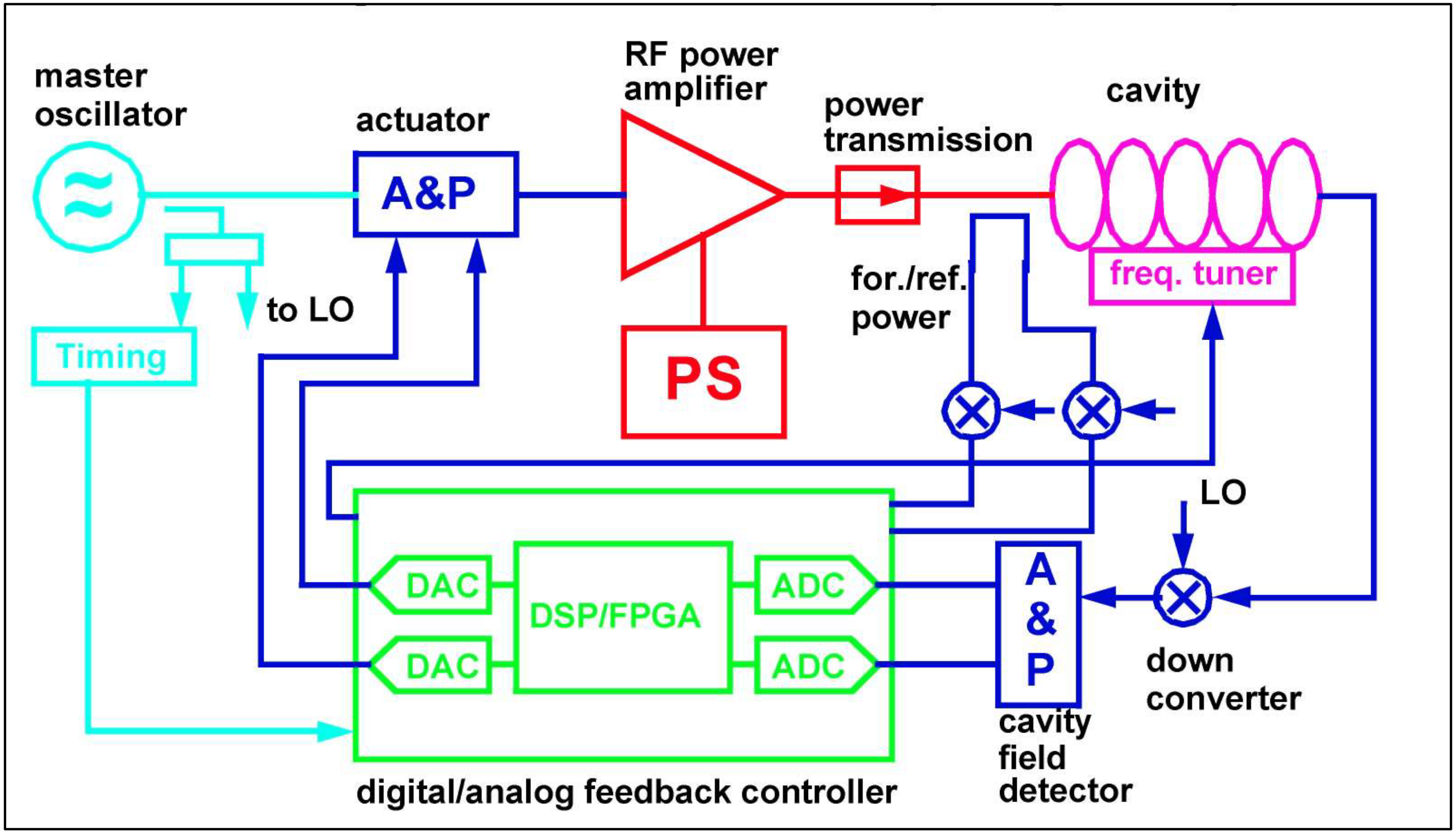
- e^- and e^+ source
- Injectors
- Damping Rings
- Main Linacs
- Crab cavities at IP



RF Station at Main Linac

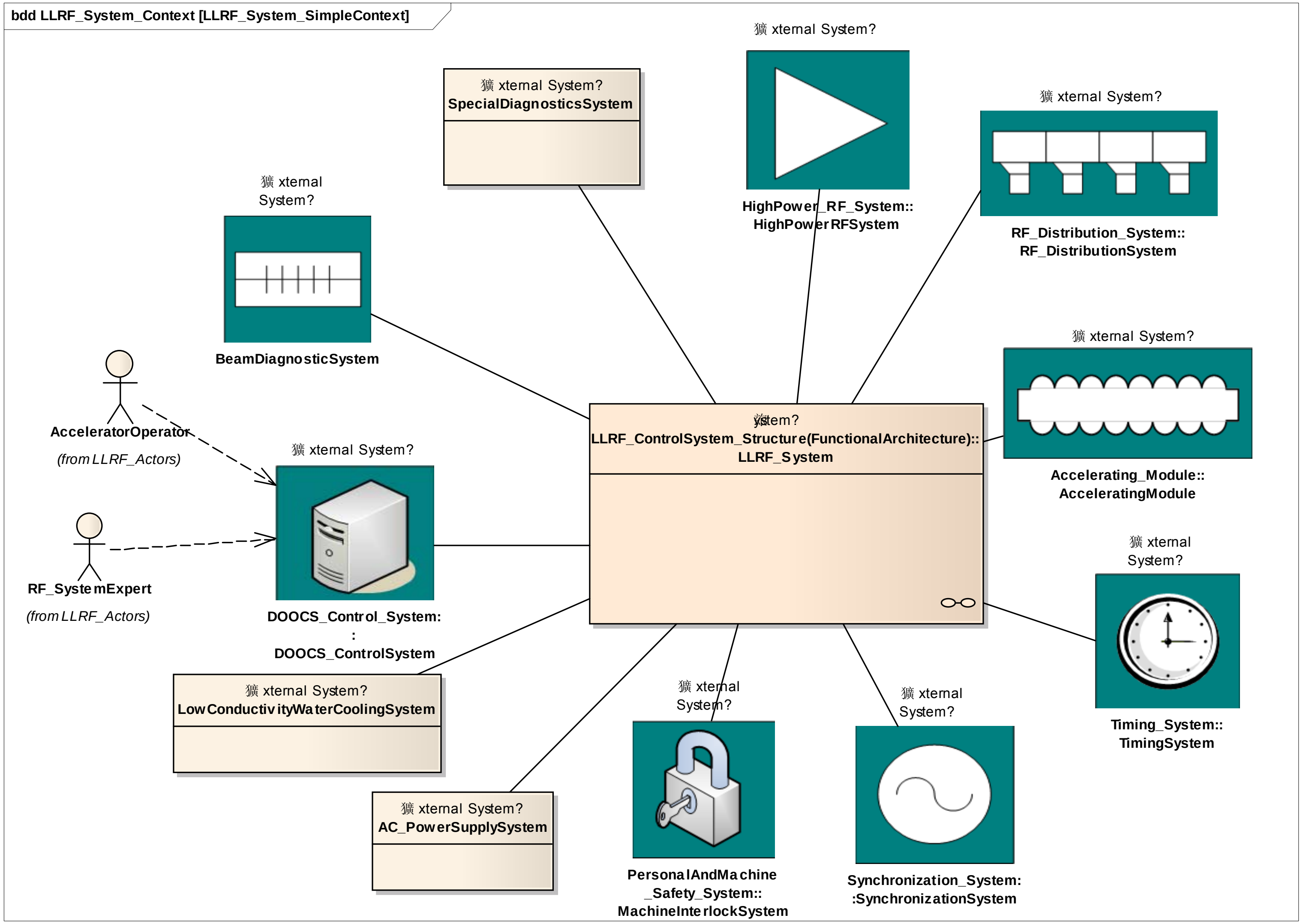


RF System Architecture



LLRF System Context

- Interacting subsystems and actors to LLRF



Scope of Main Linac RF

total number of klystrons / cavities per linac	~ 280/ 7,280
per rf station (klystron):	
# cavities / 10 MW klystron	~ 26
# of precision vector receivers (probe, forward, reflected power, reference line, beam)	~78
# piezo actuator drivers / motor tuners	~ 26/26
# waveguide tuner motor controllers	~ 26
# vector-modulators for klystron drive	1
Total # of meas. /control channels per linac	~22,000 / ~22,000

LLRF System Requirements Overview

- Maintain Phase and Amplitude of the accelerating field within given tolerances
  - up to 0.07% for amplitude and 0.24 deg. for phase

- Minimize Power needed for control

- RF system must be reproducible, reliable, operable, and well understood.

- Other performance goals
  - build-in diagnostics for calibration of gradient and phase, cavity detuning, etc.
  - provide exception handling capabilities
  - meet performance goals over wide range of operating parameters

LLRF System Requirements – Field Stability

- Derived from beam properties
  - energy spread
  - Emittance
  - bunch length (bunch compressor)
  - arrival time

- Different accelerators have different requirements on field stability (approximate RMS requirements)
  - 1% for amplitude and 1 deg. for phase (example: SNS)
  - 0.1% for amplitude and 0.1deg.for phase (linear collider)
  - up to 0.01% for amplitude and 0.01 deg. for phase (XFEL)

- Note: Distinguish between correlated and uncorrelated errors

Field Stability Requirements for Main Linac

TABLE 3.9-1
Summary of tolerances for phase and amplitude control. These tolerances limit the average luminosity loss to <2% and limit the increase in RMS center-of-mass energy spread to <10% of the nominal energy spread.

Location	Phase (degree)		Amplitude (%)		limitation
	correlated	uncorr.	correlated	uncorr.	
Bunch Compressor	0.24	0.48	0.5	1.6	timing stability at IP (luminosity)
Main Linac	0.35	5.6	0.07	1.05	energy stability $\leq 0.1\%$

- Field stability requirements (@ ML and BC) are < 0.24deg. for phase and 0.07% for amplitude
- In order to satisfy these requirements, feedback (FB) with proper feed forward (FF) control will be carried out.

Functional Requirements

- Measurements
  - Signals
  - Conditions
  - Components characterization
- Control actions
- Diagnostics
- Generate events
- Exception detection and handling
- Automation (of operational procedures)
- …

Non-Functional Requirements

- Reliability
  - not more than 1 LLRF system failure / week
  - minimize LLRF induced accelerator downtime
  - Redundancy of LLRF components
  - ...
- Operability
  - “One Button” operation (State Machine)
  - Momentum Management system
  - Automated calibration of vector-sum
  - ...
- Reproducibility
  - Restore beam parameters after shutdown or interlock trip
  - Recover LLRF state after maintenance work
  - ...

Non-Functional Requirements (C'tnd)

- Maintainability
  - Remote diagnostics of subsystem failure
  - "Hot Swap" Capability
  - Accessible Hardware
  - ...
- Well Understood
  - Performance limitations of LLRF fully modelled
  - No unexpected "features"
  - ...
- Meet (technical) performance goals
  - Maintain accelerating fields - defined as vector-sum of 26 cavities - within given tolerances
  - Minimize peak power requirements
  - ...

Summary

In this part, we have learnt:

- The basic ILC requirements
- The RF system architecture and LLRF context
- LLRF functional and non-functional requirements

Reference

[1] ILC_RDR_Volume_3 – Accelerator

[2] The ISO/IEC 9126 Standard for the evaluation of software quality

[3] Tim Weilkiens. Systems Engineering With SysML/UML: Modeling, Analysis, Design. Elsevier Science & Technology Books, 2008