Instrumentation Technologies Activities

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DITANET 1st Annual Meeting - Royal Holloway, Egham, UK, 3.4.2009

The Perspective

Extremely low emittance synchrotron light sources: Petra-III and NSLS-II emittance goals of less than 1 nm-rad.

Beam stability of ~ 10% => sub-micron orbit correction.

Ultra high brightness FELs: B ~ 10^{33} Ph/[s.mrad^2.mm^2.0.1% bw]

Overlap of photon beam & electron beam to sub-micron levels

RF Phase and amplitude stability of ~ 0.01° and 0.01%

High luminosity Colliders: ILC ~2 × 10^{34} cm^{-2}.s^{-1}

nm sized beams at IP : ~ 640 × 5.7 nm (horiz x vert)

The context
Instrumentation Technologies

Our Focus

Particle Accelerators and their Figures-of-Merit: Brilliance, Luminosity, Lifetime => Stability

Beam Stability

Stability means having synchronized, connected, dynamic state-of-the-art instrumentation, working together as one system with the means to act on the beam.

What do we do

Provide instrumentation to observe and enable beam manipulation.

How do we do it

Combining technology and people (knowledge and experience) for innovative solutions.

Important technological innovations for achieving cutting edge performance

- Software defined radio
- *Sub ps* synchronization over large distances
- Super-fast feedback systems
- Massively parallel real-time data processing

People - Company

> 45 people, 8 Ph.D., 14 M.Sc., 15 Engineers
Analog and Digital Engineering
High and Low Level Software

In-house design of hardware and software.

Electronic assembly and fast prototyping.

Extensive FPGA programming support.

All manufacturing is done by supporting industry with comprehensive quality control from our side.

People - Community

- **Libera Community**
  - Libera Workshop: training, teaching, technical products' presentations and discussions, users' contributions, exchange of experiences and ideas
  - Libera users' meeting: Libera Wishlist for future improvements of Libera products
- **People exchange:**
  - FP6
  - FP7: DITANET
  - Industrial sabbaticals
- **Strong R&D team**
- **Co-development with launch customers**
- **Shared experience from institutes**

Capabilities

- Complete in-house development
- System engineering (*TCA)
- Analog signal processing
  - RF (up to 12 GHz)
- Hardware engineering
  - Mixed signal design
  - ADCs: state-of-the-art, DACs: state-of-the-art
- FPGA (ASIC) & DSP
- Multi-Gigabit serial links (FiberChannel, GbE, PCIe, Protocol-less, ...)
- High speed interfacing (LVDS)
- Software Engineering
  - Linux: drivers, APIs, real-time operation, networking
  - GUI
  - EPICS, TANGO
- Timing & Synchronization (to 100 fs and less)

Quality, Craftsmanship & Support

Production testing
Final performance testing
Software/firmware releases updated
Automated testing avoiding human error
Full warranty
Comprehensive customer support

Libera Concept

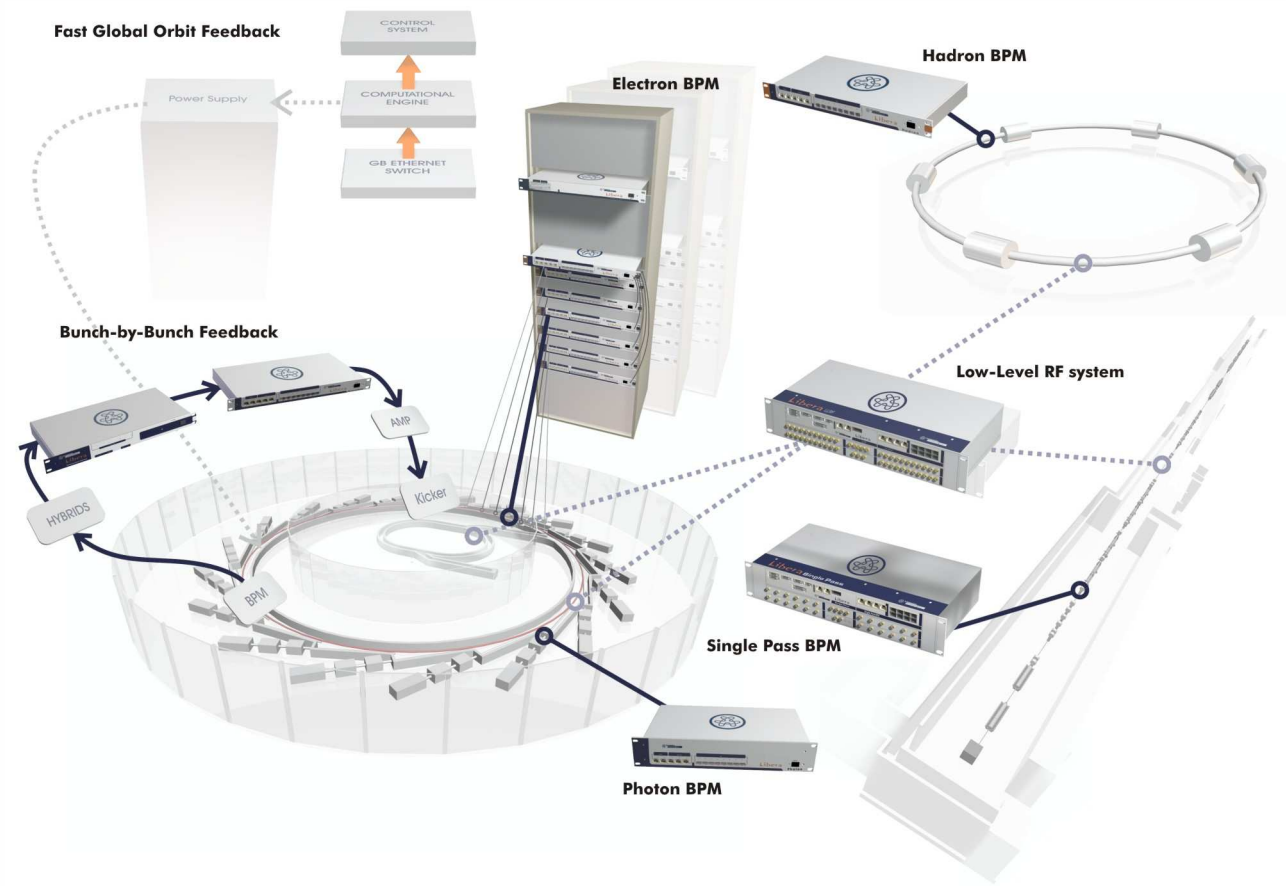
All-in-one solution
Integrated architecture
From analog to GUI
Reconfigurable
Feedback-ready
Network Attached

Commissioning
Operations
Beam Physics

Launch Customers
Initial development with
SOLEIL and DIAMOND

Instrumentation Technologies

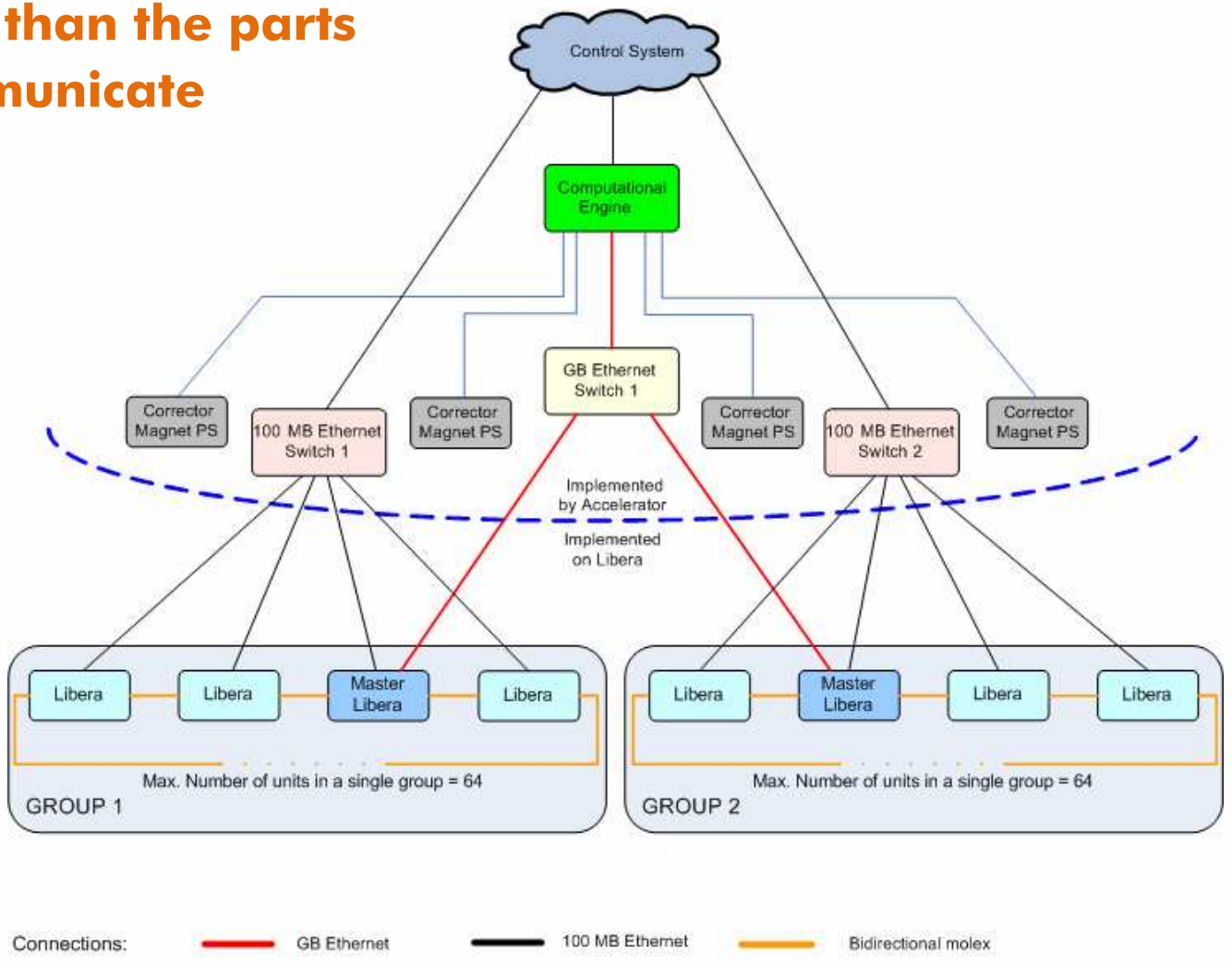
Accelerator Systems: Instrumentation and Diagnostics



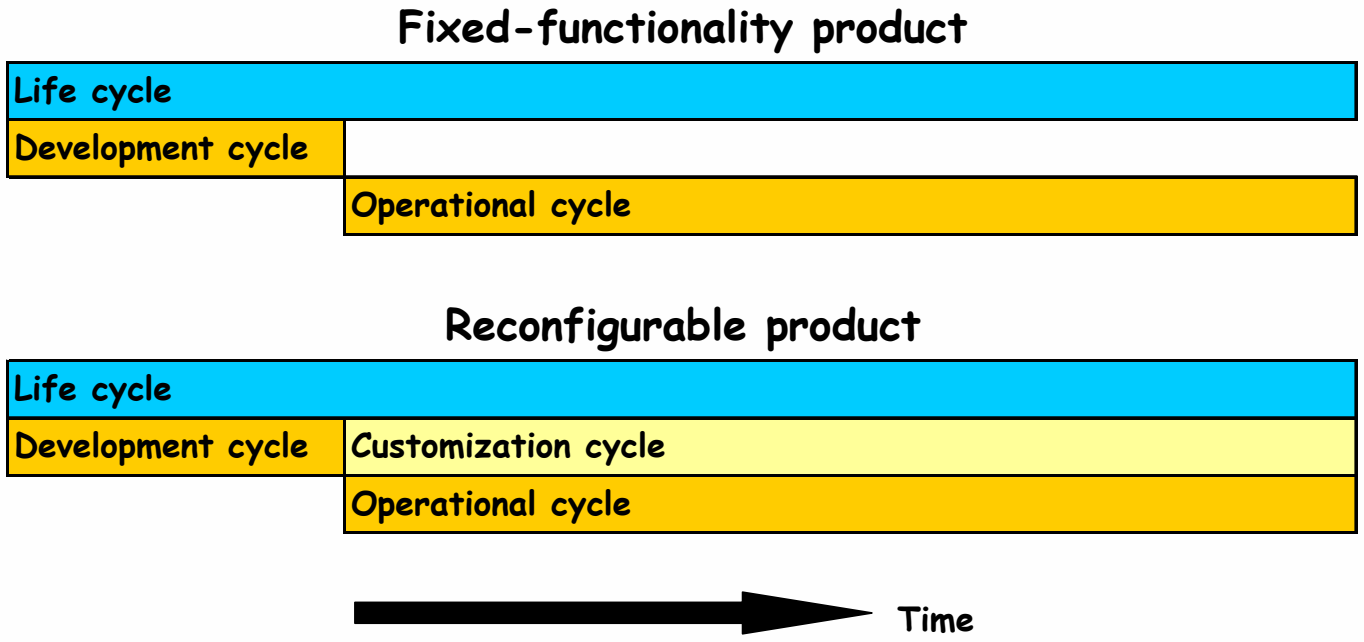
Fast Orbit Feedback

The sum is more than the parts
Group and Communicate

Fast Orbit FB
- **Centralised**
- **Distributed**



Black Box or Sand Box



A tool for basic science is more effective if reconfigurable by both the manufacturer and the end User.

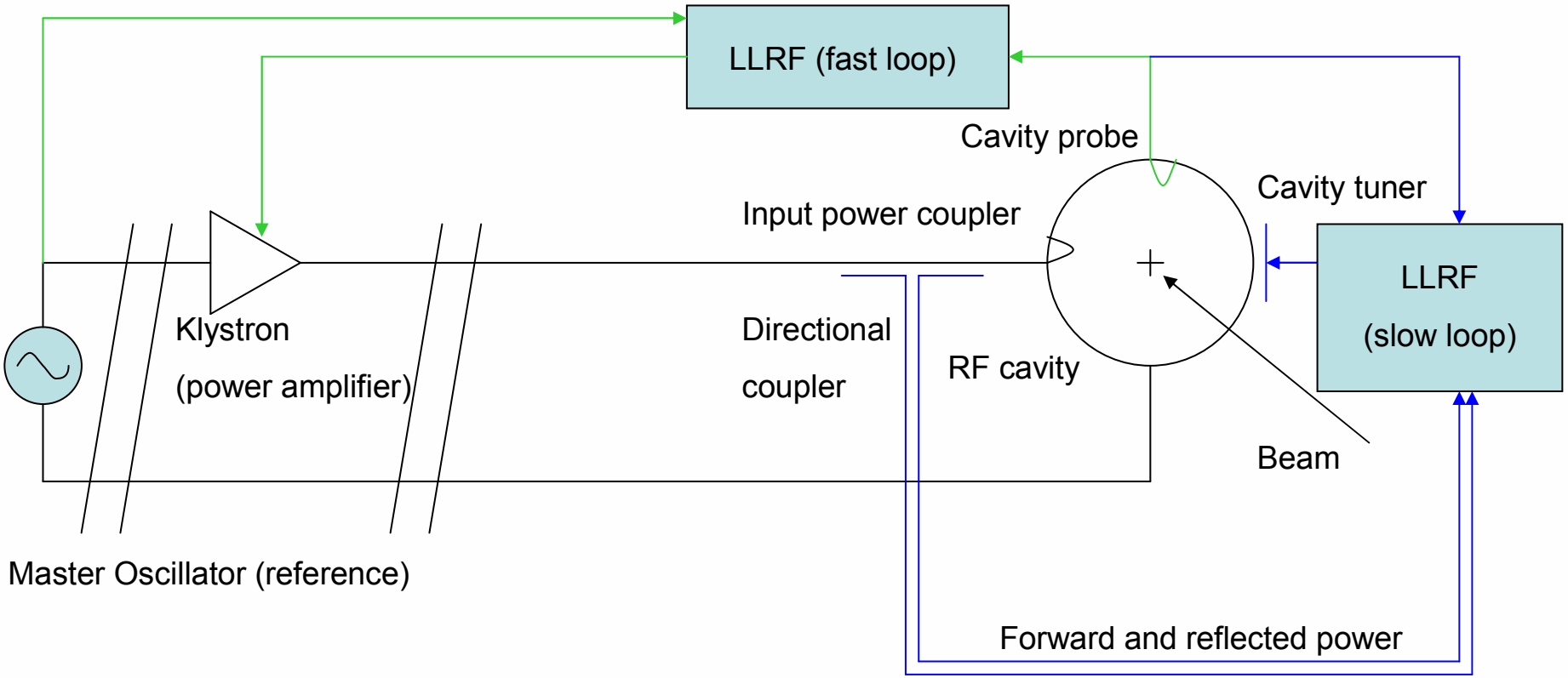
Developing the Product

- Specifications – User Input, Experience, Launch Customer
- Use of industry standards – Look into the future
- Integrated design – Hardware and Software, Flexibility
- Resources – Hardware/Software: 1/6 to 1/10 (digital world)
- Early involvement of QA and Product Managers (represent the end user)
- In depth Quality Control and system testing
- Maintenance program – project/product overlap
- Meet the specifications on time
- Post-mortem – identification of best practices
- Product support – tracking

Developing the Project

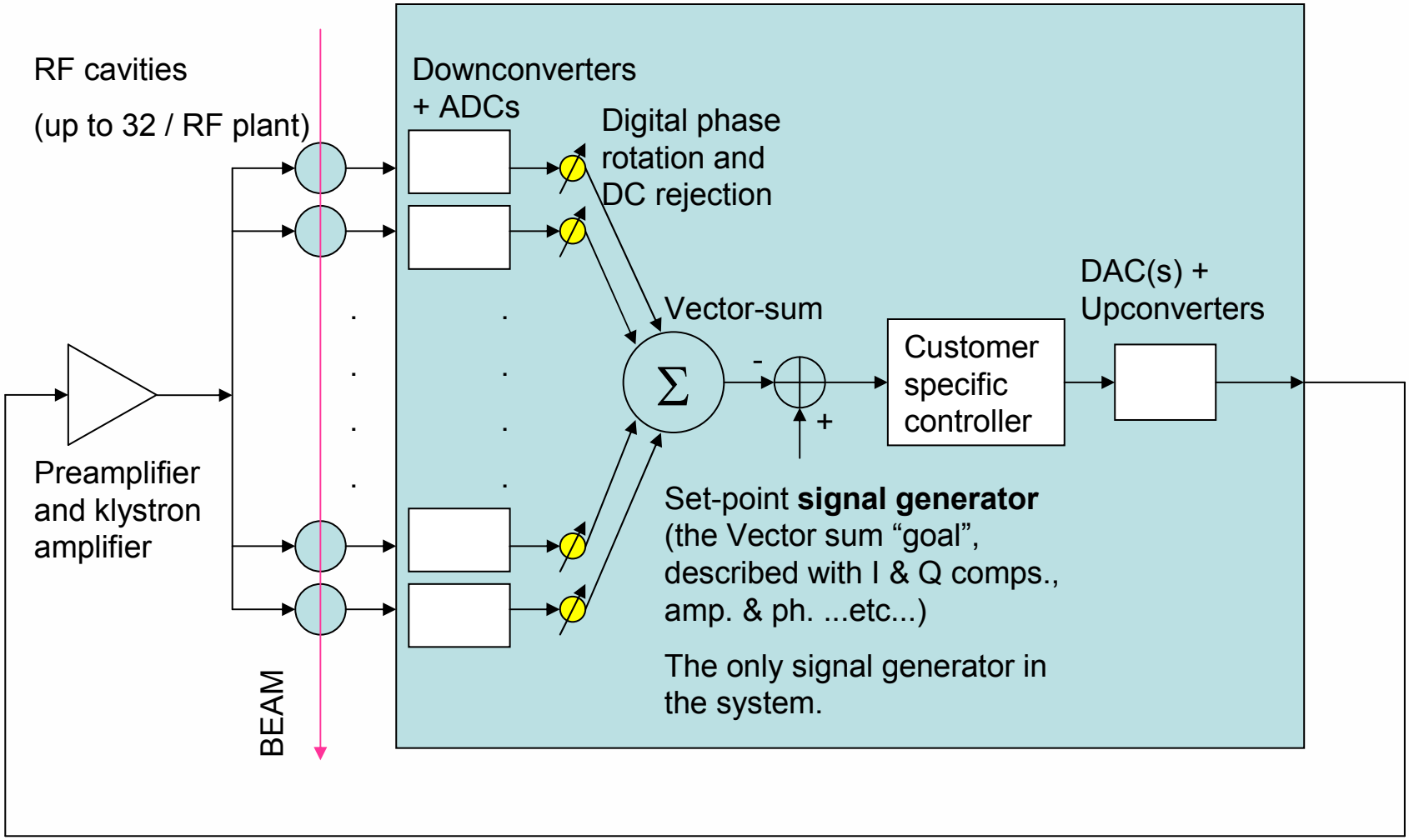
- Project Management tools, Statements, Work Orders
- Complete specifications and resource allocation
- Team by name, Grouping
- Regular review meetings (daily – individual reporting, weekly - team)
- Hardware re-spins (usually one or two)
- Rigorous bug reporting and database maintenance (HW & SW). Priorities.
- Rigorous procedures including certification.
- Be prepared for prioritizing and conflicts.

Example LLRF



Example LLRF

LLRF System (implementing the cavity field stabilization)



Hardware Interfaces

Intel dual core COM Express with extensive communication interfaces:
The latest FPGAs and a powerful personal computer based on the PCIe interface offer good resources for the implementation of low-latency control algorithms, real-time data processing and dedicated RF system diagnostics tools.

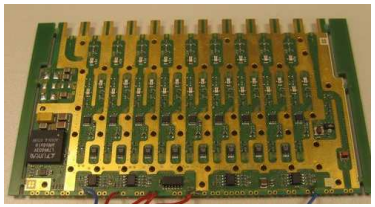
Vector modulator module:
Receives the partial vector sum signals from four satellite ADC modules through low-latency low-voltage differential signaling (LVDS) lines. The global vector sum is then processed by means of FPGA algorithms. The output of the control algorithms is then up-converted to the RF frequency and used as the transmitter drive signal.

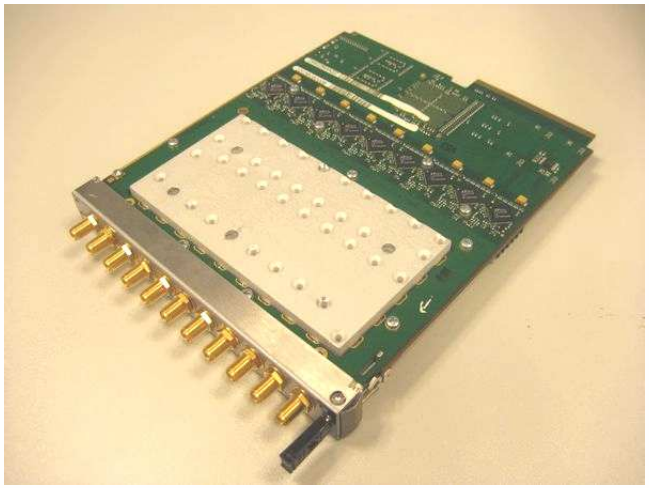
Optional fast communication modules

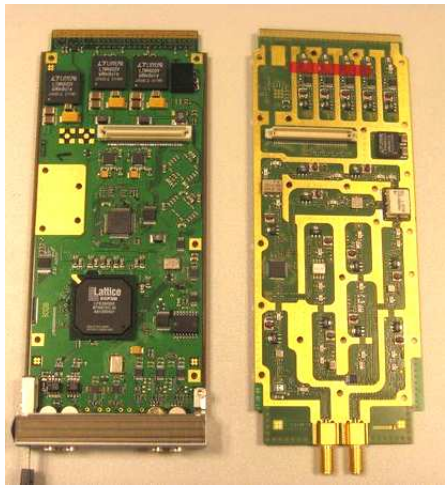
Timing module:
Generates a low jitter local oscillator (LO) signal and a suitable sampling clock for the down-conversion and acquisition processes. The designed acquisition structure enables a high level of amplitude and phase cavity field stabilization.

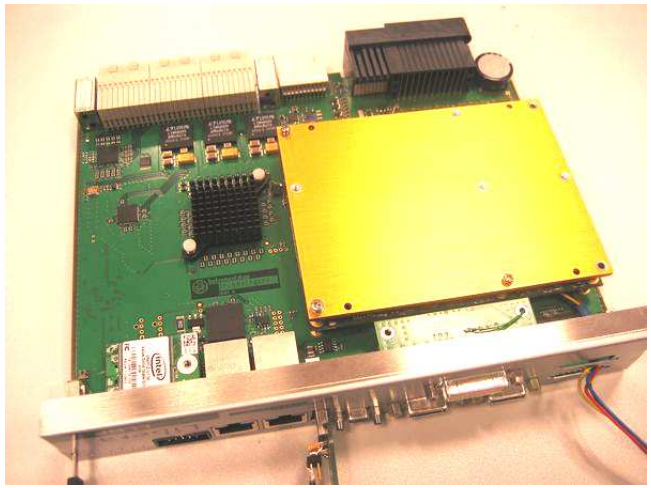
RF acquisition modules:
The system is configured to have four satellite modules, each of which can process up to 9 RF inputs. One channel on each board is used as RF reference signal for measurement and jitter cancellation purposes. Each RF acquisition module includes a built-in calibration system, temperature stabilization, jitter cancellation, LO distribution, partial vector sum computation and vector sum phase alignment functions.

Libera LLRF









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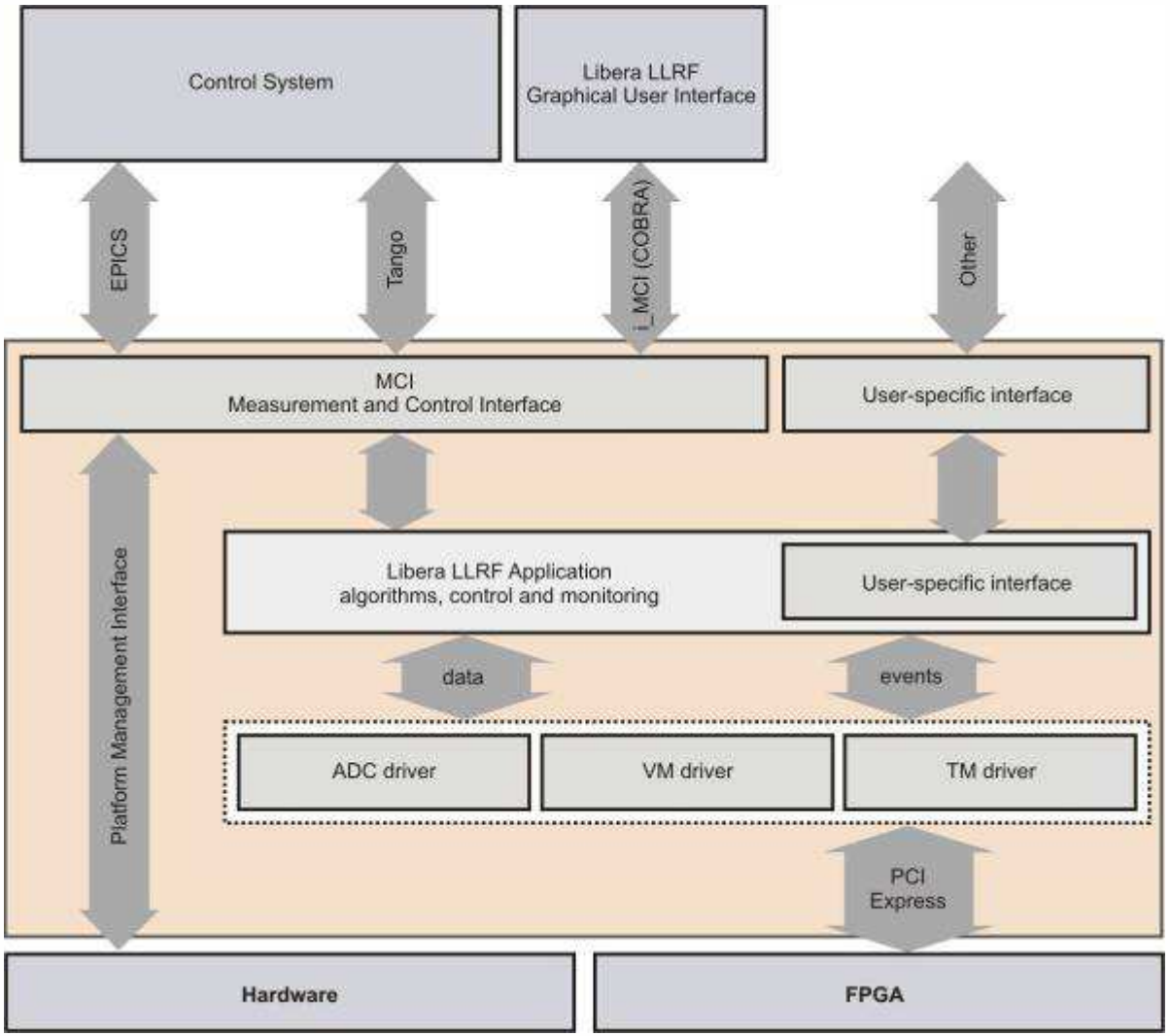
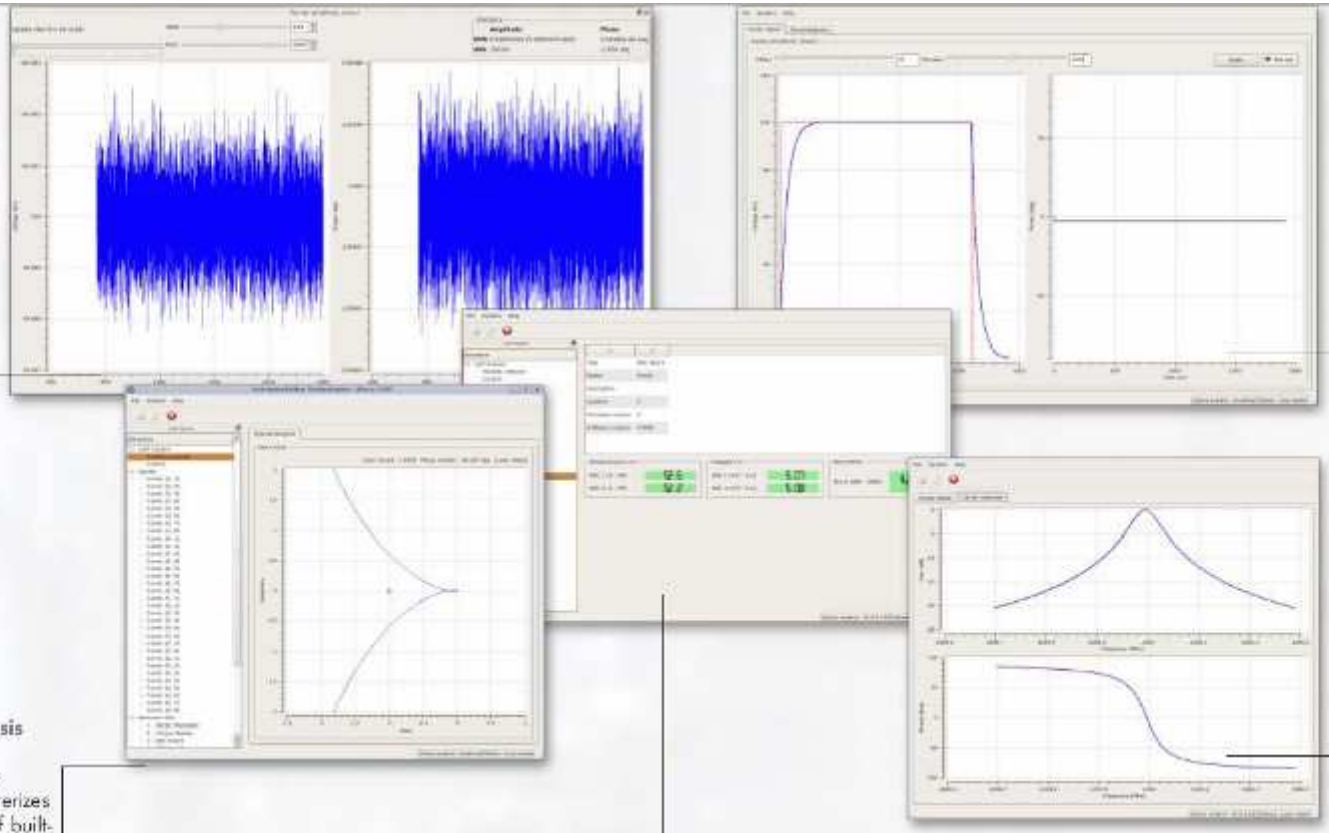
Libera LLRF - Software



Libera LLRF - GUI

Flat top analysis

The cavity voltage amplitude and phase stability can be easily measured from the acquired samples. A long history of raw samples is available from the buffer. The effectiveness of the control algorithms in suppressing disturbances of the cavity field, can be measured using this tool.



Decimated signals

All the signals of the Libera LLRF system are also available in a decimated form for easy processing and display on control system screens. The cavity response to RF pulses is already available in the form of amplitude and phase signals.

RF system diagnostics

During operation, the cavity decay analysis and directional coupler signals are used to monitor and control the cavity tuning.

Nyquist stability analysis

A powerful RF diagnostics system completely characterizes the RF system by means of built-in network vector analysis. Libera LLRF automatically uses diagnostic measurements to compute the optimal phase rotation for enabling a stable LLRF loop. The user is also provided with phase and gain stability margins. The open loop transfer function is displayed on a Nyquist diagram. The application suggests the optimum working parameters.

System monitoring

The Libera LLRF system has an advanced health monitoring system that takes care of fans, voltages and temperature.

Parameters

Configurable LLRF controller application

Parameter	Value
Number of input channels	36 (9 per module)
ADC resolution	16 bits
Max. ADC sampling clock frequency	130 MHz

Similarities & Differences

Research Infrastructures & Industry

Creating a product or building a facility have similar tasks.

Facility	Product
User requirements	Customer Needs
Available Technology	Available Technology
Project Management	Project Management
Operations	Manufacturing
Upgrades	Product Support

Differences

Time Scale – Long	Time Scale – Short
Project Publicly Funded	Private Investment
Operation Publicly Funded	Sales

Thank You