HIAF (High Intensity Heavy-ion Accelerator Facility) Synchrotron LLRF R&D

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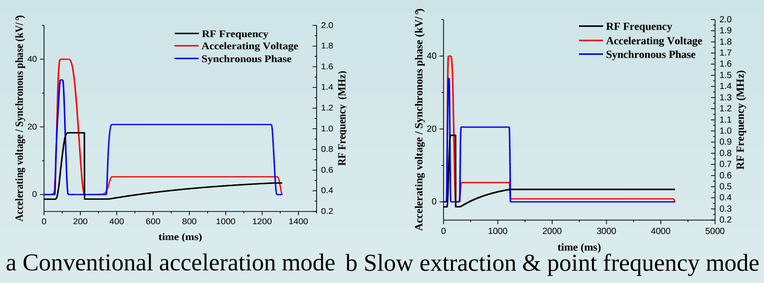
Introduction

According to the task of the HIAF (High intensity Heavy-ion Accelerator Facility) synchrotron project undertaken by the Institute of Modern Physics, Chinese Academy of Sciences, we need to develop a RF system of a MA core loaded cavity. The RF system is mainly consists of four parts: MA loaded cavity, high power pulse power source, full digital LLRF and computer control system.

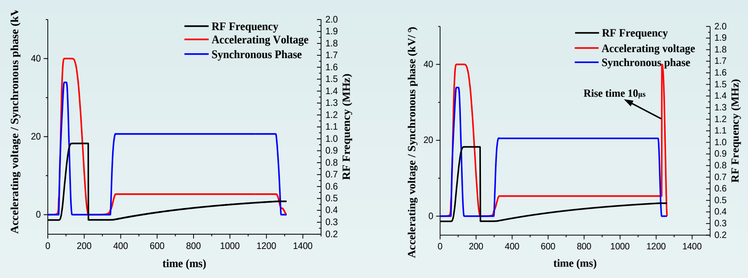
Table 1 is the specification of the RF system of the MA loaded cavity, figure 1 shown the accelerating voltage, synchronous phase and RF frequency with time of the four operating mode.

Specification of RF system of the MA loaded cavity

Working frequency	0.29~0.98 MHz
Repetition frequency	0.33 Hz
Duty cycle	50%
Working mode	Sweep frequency mode
Peak voltage	40kV
Minimum voltage	1kV
Voltage rise time	10μs
Phase stability,	≤|1° |
Amplitude stability	≤|1×10^{-2}|



a Conventional acceleration mode b Slow extraction & point frequency mode



c Length & momentum dispersion regulation model d Bunch rotation mode

Figure.1 Curve of Four Operating Mode

LLRF Requirement

1) Cavity amplitude and phase loop. Regulate the amplitude and the phase of the cavity voltage.

2) Beam loading compensation. Use Feed-forward to cancel the beam loading effect.

3) Synchronous phase control loop. Damp the longitudinal dipole oscillation.

4) Radial feed-back loop. Adjust the working frequency according to BPM signal.

5) Load amplitude, synchronous phase and working frequency set value from data file.

6) All digital system.

7) Hardware base on cPCI bus.

8) EPICS interface.

Cavity Structure

MA loaded cavity has the advantages of high impedance, wide band, fast response speed, high acceleration gradient. the cavity plan to use Fe-based nano magnetic alloy core as loading material.

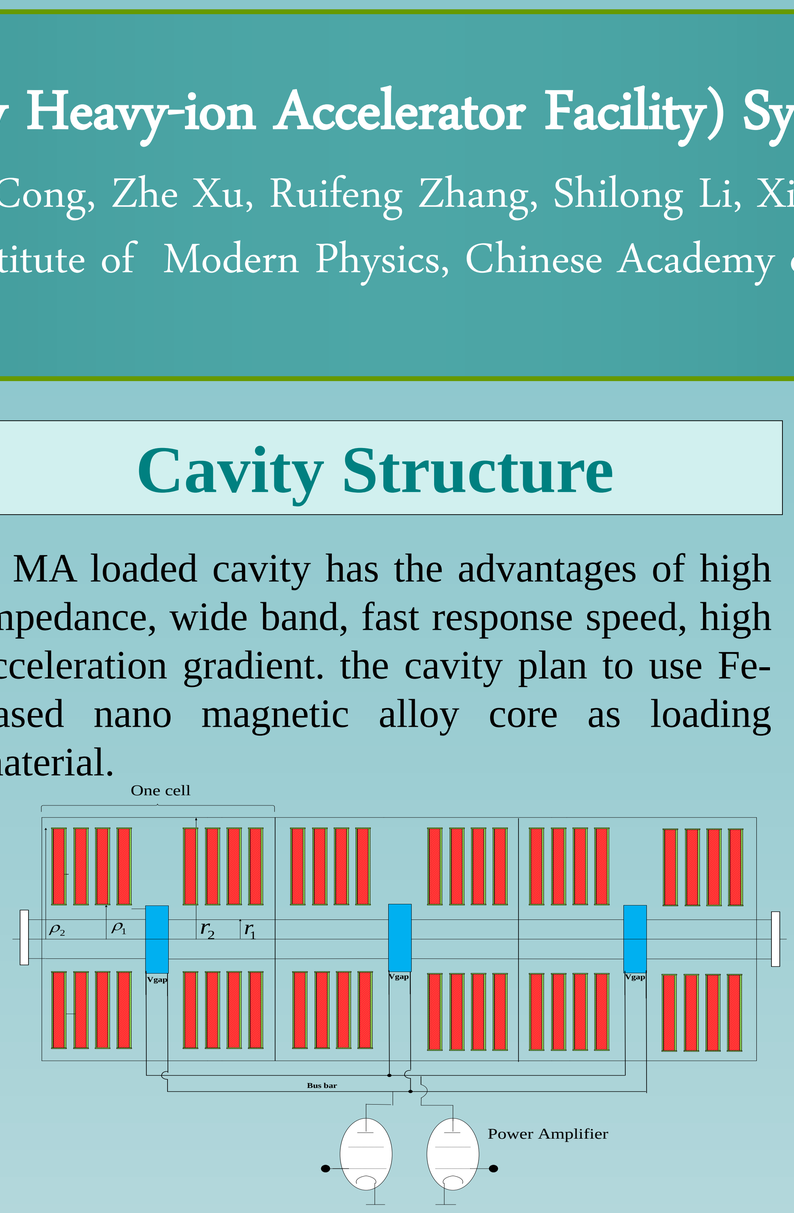


Figure.2 Structure of MA Loaded Cavity

Multi-Control Loops

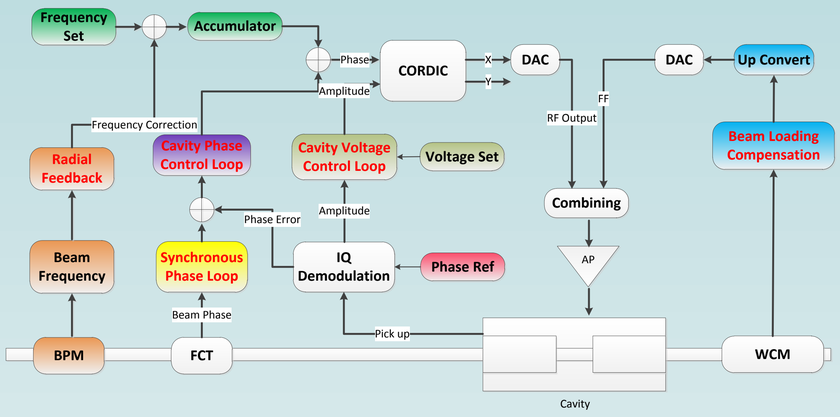


Figure.3 Reference Principle Diagram of the Multi-Control Loops

Beam Loading

Two methods will be used to compensate the beam loading, one is analog direct feed back, the other is feed forward.

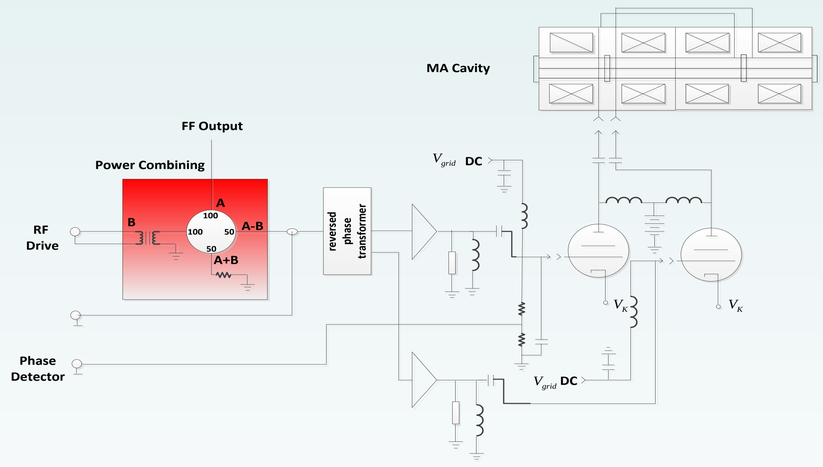


Figure.4 Schematic Diagram of Direct Feed-back Transmitter

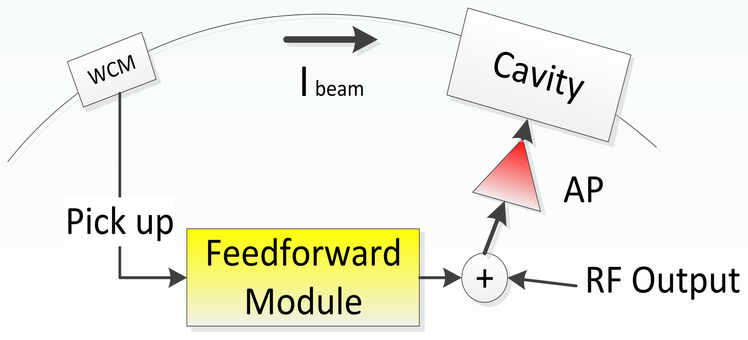


Figure.5 Schematic Diagram of Direct Feed-back Transmitter

Hardware

LLRF board is a signal processing board, which is designed base on Xilinx V5 series chip.

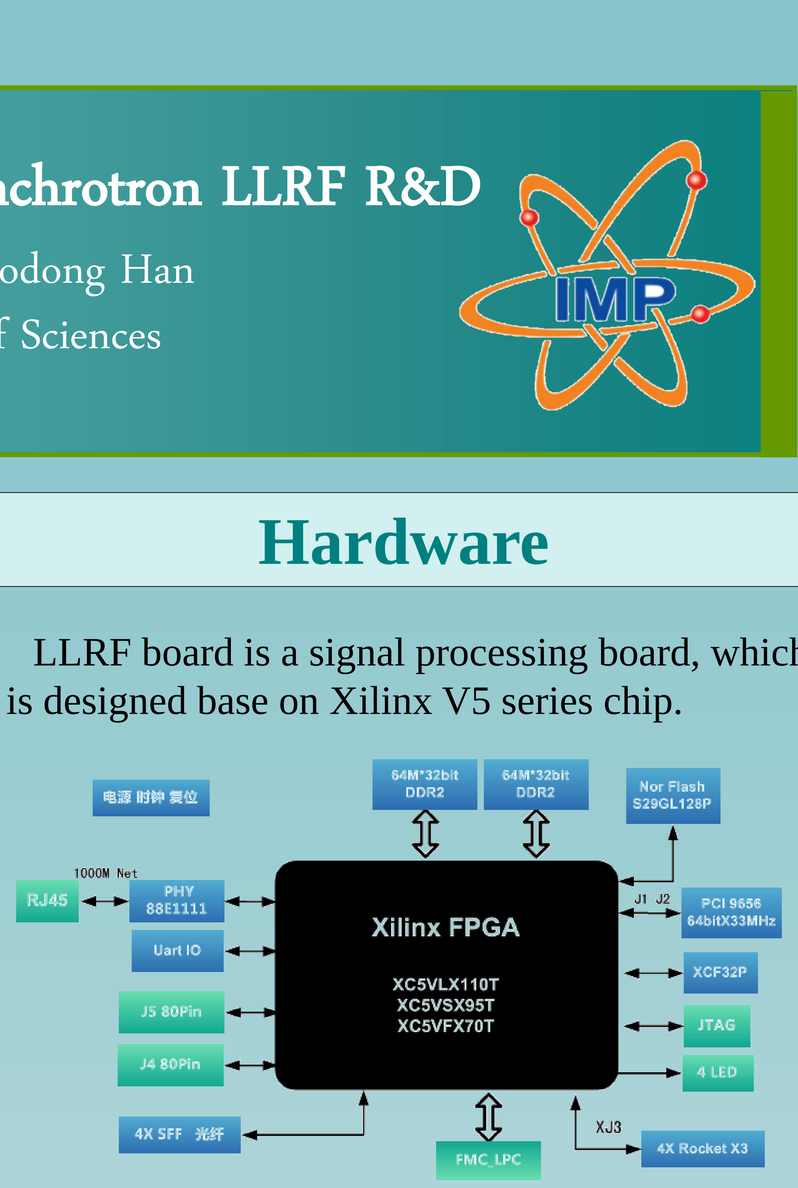


Figure.6 LLRF Board Topology

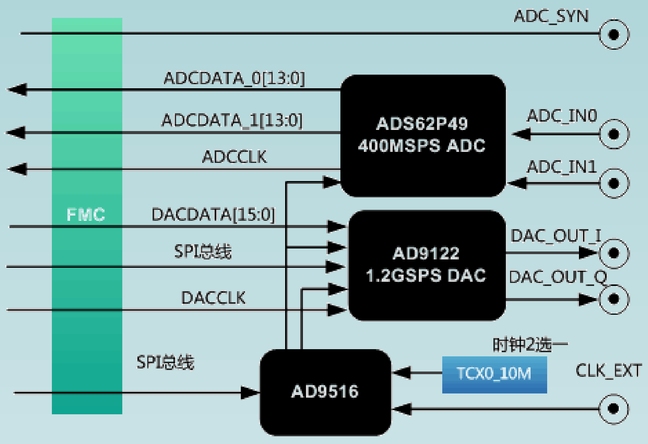


Figure.7 ADC/DAC Board Topology

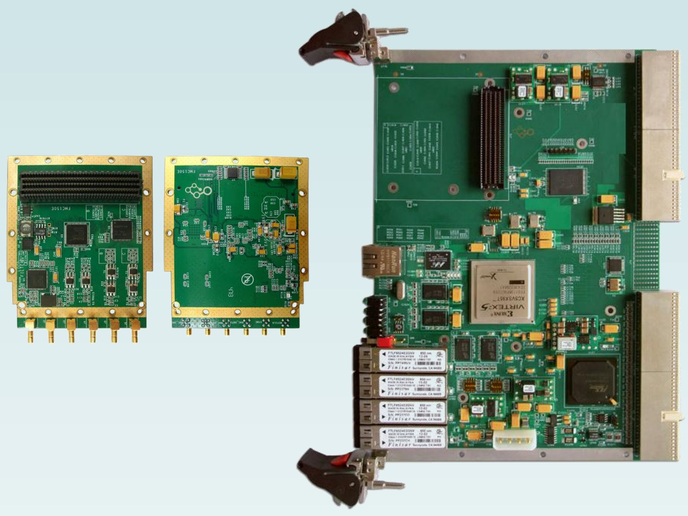


Figure.8 LLRF Board

Challenge

1) Beam loading compensation

It's a new thing for us. We should carefully calculate the change of cavity impedance caused by beam current.

2) low operating frequency

In order to obtain the zero IF signal after quadrature demodulation, we need to reduce the sampling rate. But this will reduce the system's response speed.

3) Big dynamic range of cavity impedance

The parallel impedance of cavity will change from 330~450Ω/gap with frequency from 0.29 ～ 0.98MHz. The amplitude stabilization loop requires a large dynamic range.

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