Performance of RF System for cERL Injector in KEK

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ERL-2013, 9-13 September, 2013, at BINP, Novosibirsk, Russia
Introduction

Compact ERL (cERL) is under construction as a test facility for 3-GeV ERL future plan.

Construction of the injector was finished until 2013 April. First beam commissioning at the injector was performed for 2 months from this April to June.

Main linac is under construction now. Construction of the whole cERL will complete until middle of November 2013. Beam commissioning will start this December.

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RF Power Sources for Injector

- Gun
- Buncher
- 2-cell Superconducting cavities
- CAV1
- CAV2
- CAV3
- 5 MeV
- Loaded Q
  - CAV1: $1.2 \times 10^6$
  - CAV2: $5.8 \times 10^5$
  - CAV3: $4.8 \times 10^5$
- RF freq=1.3 GHz

Requirements of RF stabilities:
- 0.1% rms, 0.1 deg.rms for cERL
- 0.01% rms, 0.01 deg.rms for 3GeV-ERL

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RF Power Distribution System (outside shield)

- 20 kW IOT
- 25 kW Klystron
- 300 kW Klystron

To buncher

To cav1
To cav2
To cav3

Phase Shifter

Phase Adjustment between CAV2 and CAV3

Buncher

Double-feed 2 cell cavity

Gun

20 kW IOT
25 kW Klystron
300 kW Klystron

Outside shield
RF power distribution system (inside shield)

Space is narrow and very complicated.

Phase shifter ($\pm 33.5^\circ$)
: match RF phase between top and bottom input-couplers
Digital Low Level RF System

<table>
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<tr>
<th>BUN</th>
<th>CAV1</th>
<th>CAV2</th>
<th>CAV3</th>
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<td>Feedback board</td>
<td>FB0</td>
<td>FB1</td>
<td>FB2 (Vector-sum)</td>
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<tr>
<td>Tuner board</td>
<td>TN0</td>
<td>TN1</td>
<td>TN2</td>
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- FPGA boards
- Downconverter
- IQmodulator
- Feedback board
- Tuner board
- AMC (Advanced Mezzanine Card)
- µTCA Digital Board
  - FPGA Virtex5-FX (LTC2208)
  - 16-bit ADC x 4
  - 16-bit DAC x 4 (AD9783)
- Clock input
- Ref Clock
Schematic Diagram of Digital FB System

LO 1310MHz

Down converter

1300 MHz

Klystron

PreAmp

RF switch

Interlock

Digital feedback board

Digital Filter

Vector Sum

IIR Filter

I Set Table

LFF Table

Delay

Correction

rotation

Limit

ADC

FPGA

ADC

ADC

ADC

AMC Digital Feedback Card

16bit 80MS/s

1300 MHz

MO/128

1310MHz

\[ A = \begin{pmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{pmatrix} \]

\[ Q = \begin{pmatrix} \cos\phi \\ \sin\phi \end{pmatrix} \]

\[ R = \begin{pmatrix} \cos\theta \\ -\sin\theta \end{pmatrix} \]

Power PC

Linux

EPICS IOC

Gb Ethernet

Set Parameters

Wave Forms

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μTCA digital board was used for tuner control.

Slow piezo-tuner feedback was performed through EPICS in this commissioning.
Stabilities of Cavity Fields

FB0 (Buncher)
- Amp: 0.05% rms
- Phase: 0.06 deg. rms

FB1 (CAV1)
- Amp: 0.01% rms
- Phase: 0.02 deg. rms

FB2 (Vector-sum)
- Amp: 0.01% rms
- Phase: 0.022 deg. rms

100kS/s
300Hz ripple from power supply

RF stabilities satisfy the required stabilities of 0.1%rms, 0.1deg.rms
Waveforms of FB2 (vector-sum)

Amplitude: 0.01% rms

Phase: 0.022 deg. rms
Measurement of Beam Momentum Jitter

Beam : 5nA (5Hz, 0.77pC/Bunch, 1ps rms, Macro pulse=1μs)  
Small current & short length

Buncher was not used. (turned off)

Beam diagnostic line(Presented by Y.Honda)

Dispersi on @ screen monitor = 0.82m  
Resolution = 53.4 μm/pixel  
(ΔP/P=6.5e-5)

Momentum was determined by the peak point of the projection of the screen.
RF feedback was working, but 
Beam momentum Jitter was very large, 0.3% rms

*It caused by phase error between CAV2 and CAV3*

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Phase Optimization for Vector-sum

“Phase shifter in CAV3 line” and “feedback phase” were optimized while observing screen monitor.
(CAV2-CAV3 transit time is depends on the energy)

Phase shifter was changed to the direction to beam energy high. ( -> crest phase)

Phase shifter was changed 34mm shorter than before. (38deg)

300kW Klystron

Phase Adjustment between CAV2 and CAV3
Momentum Jitter After Phase Optimization

Momentum jitter was improved.

FB 2HG: \(\frac{dP}{P} = 0.0056858\%\) rms

Momentum Jitter = 0.006\% rms

Good stability of beam momentum was achieved.

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Summary

- Construction of RF system for cERL-injector was finished.
- Commissioning had been performed for 2-months.
- RF fields in every cavities satisfied the required stability, 0.1%rms, 0.1deg.rms.
- Good stability of beam momentum was achieved.

Future Plan

*In middle of November 2013*, operation of the whole cERL will start.

- RF system for two 9-cell cavities of the main linac (ML) should be completed until then.

- In the case of 9-cell, we should pay attention to TM_{010} passband except for π mode. To remove $8/9\pi$ mode without long latency -> IIR digital filter will be modified

- Loaded Q of ML-cavities is high, $2 \times 10^7$, therefore tuner control is very important. The tuner feedback using FPGA will apply.
Thank you for your attention.