Status of MicroTCA-based System for Accelerators in KEK

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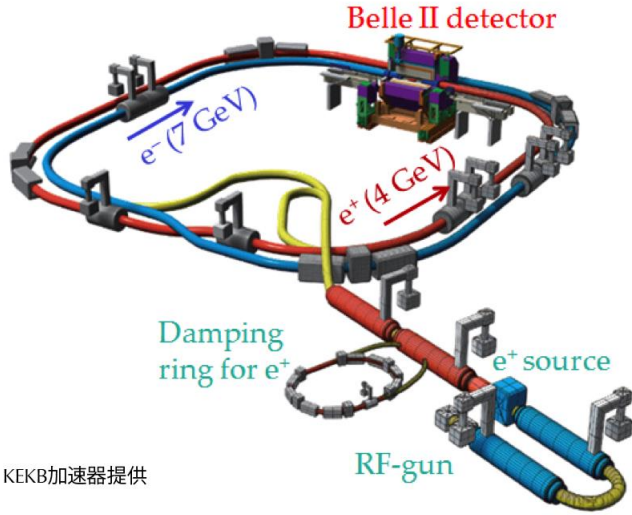
(KEK)

Outline

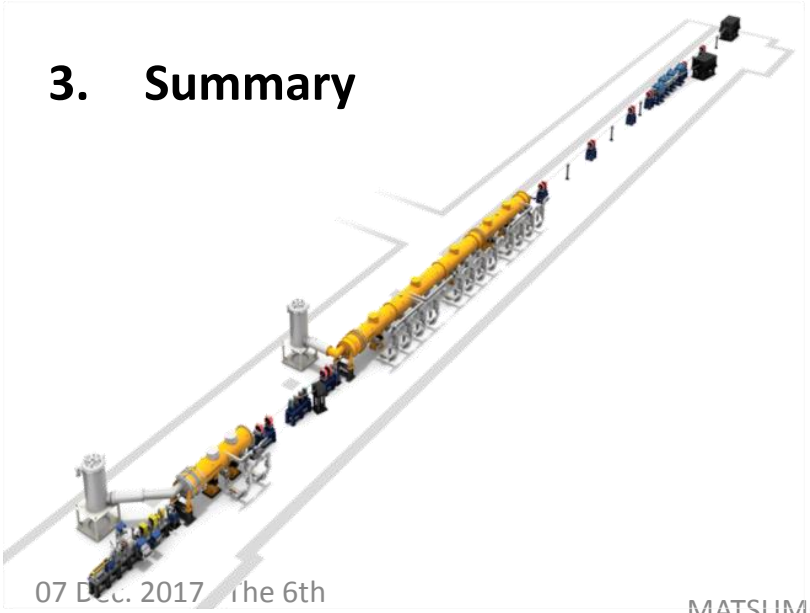
1. **MicroTCA based board developed in KEK Accelerators**

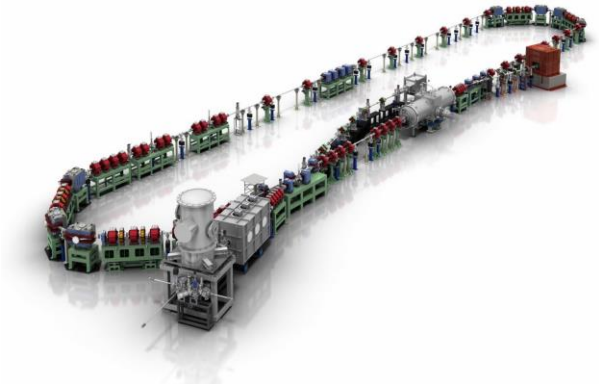
2. **Present status of KEK Accelerators using MTCAs**
   - **2-1. SuperKEKB Ring**
   - **2-2. SuperKEKB Linac**
   - **2-3. STF (Superconducting rf Test Facility)**

3. **Summary**



KEKB加速器提供





Facilities using MTCA at KEK

High Energy Accelerator Research Organization (KEK) @ Tsukuba site, Japan

SuperKEKB

Upgrade project from KEKB

- Aiming at 40 x L of KEKB
- Asymmetry double ring collider of e^+ & e^-. (circumference:~3km)
- To Explore new physics beyond the standard model
- 509-MHz RF, NC&SC, CW op.

STF

Superconducting Test Facility

- R&D facility for ILC RF system.
- 1.3-GHz RF, SC, Pulse op.

cERL

Compact Energy Recovery Linac

- Test Facility for a future 3-GeV ERL
- 1.3-GHz RF, SC, CW op.

- 114 MHz, 571MHz, 2856 MHz RF, NC, Pulse op., 600 m in length

By courtesy of Kobayashi

MicroTCA based board developed in KEK Accelerators -1-

- In 2008, the development of digital board based on MTCA.0 was started for the aim of common use at RF control among SuperKEKB, cERL, and STF in KEK.

- Digital board (Cavity field controller/monitor)
  - Multi-channels of ADC/DAC Max. 4 channels
  - FPGA (Virtex-5 FX)
    ⇒ Linux installed on PPC 400
    ⇒ EPICS-IOC running Channel Access

- FPGA (Virtex 5 FX),
- 4 x 16-bit ADCs (Max. 130MSPS)
- 4 x 16-bit DACs
- Digital I/O

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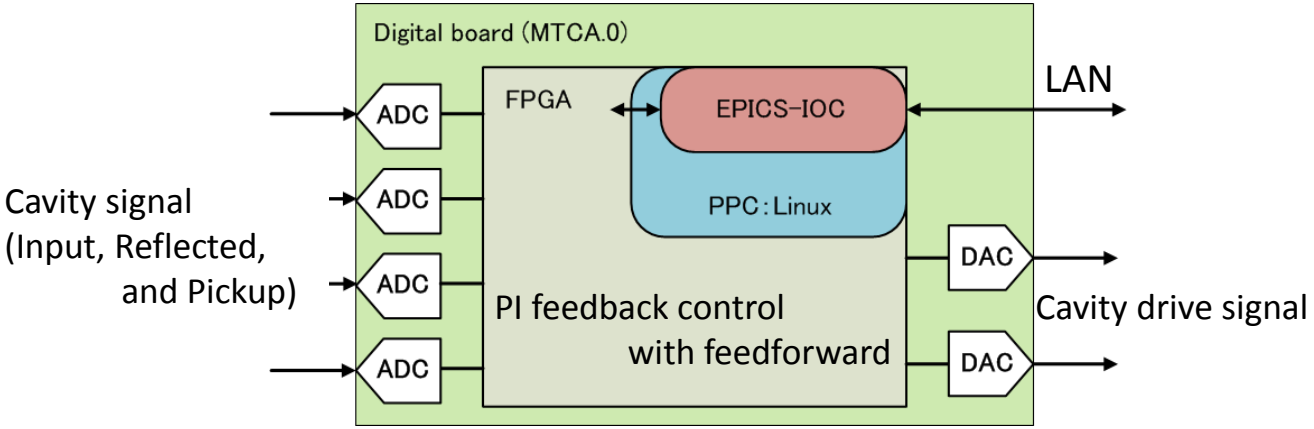


- FPGA (Virtex 5 FX),
- 2 x 14-bit ADCs (Max. 400MSPS)
- Digital I/O

Mitsubishi Electric TOKKI System Co., Ltd.

MicroTCA based board developed in KEK Accelerators -2-

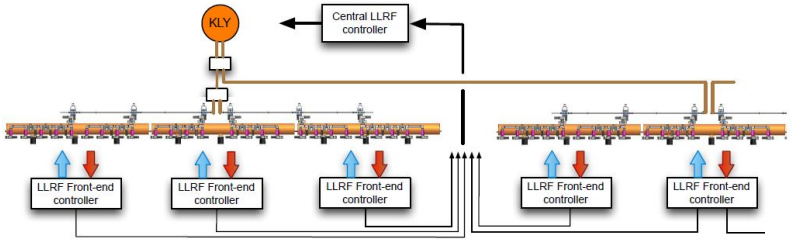
- In 2013, the development of digital board for ILC LLRF control was started.
- First candidate

4 x  + Optical link connection board + 

But… Expensive,
WindRiver Linux support for PPC is finished.
(Virtex-5 and PPC 440 ⇒ ?)

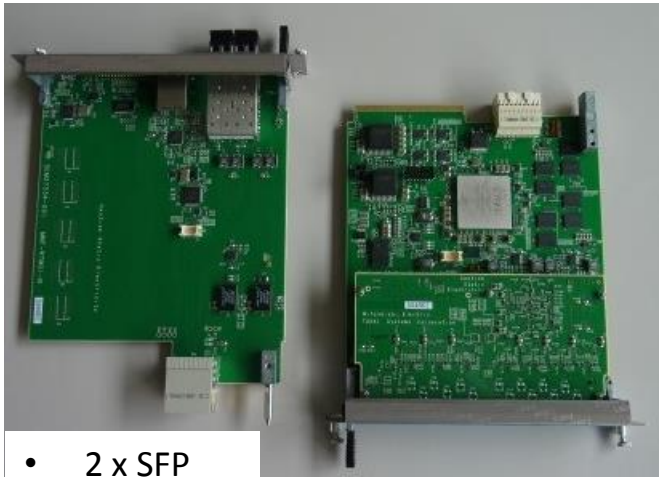
- New digital board was developed.
  - Based on MTCA.4
  - New FPGA (Zynq-7000) and CPU
    ⇒ ARM-linux installed on Cortex-A9
    ⇒ EPICS-IOC running

Configuration of ILC LLRF system



In the ILC, 39 SC cavities are operated under cavity-field vector-sum feedback control.

Newly developed board based on MTCA.4



- 2 x SFP
- 1 x RJ-45
- Digital I/O
- 2 FPGAs (Zynq-7000, Spartan 6)
- 14 x 16-bit ADCs
- 2 x 16-bit DACs

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Present status of KEK Accelerators using MTCAs

- **SuperKEKB Ring**
  - LLRF control system (feedback control)
    - => Newly installed at Damping Ring
  - Reference system (feedback control)
  - Beam Orbit feedback control at Interaction Point

- **SuperKEKB Linac**
  - Reference system (monitor => feedback control)

- **STF (Superconducting rf Test Facility)**
  - LLRF control system (feedback control)
  - Reference system (monitor => feedback control)

- **cERL (Compact Energy Recovery Linac)**
  - LLRF control system (feedback control)

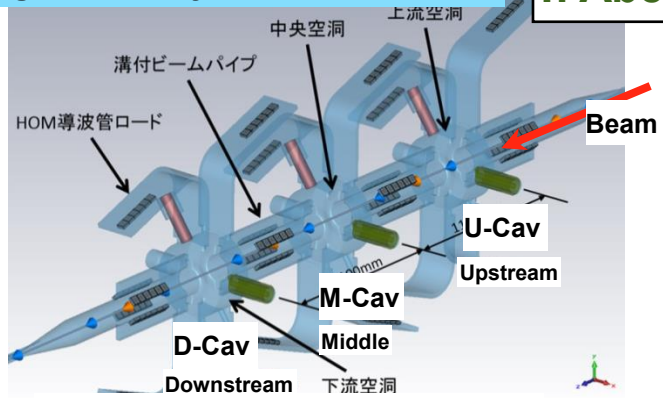
Damping Ring RF system

DR commissioning will be started in Dec. 2017 before Phase-2.
All RF system is ready for the commissioning.

DR cavities had been installed, and high power conditioning was completed successfully in June 2017.

Design of Cavity for DR

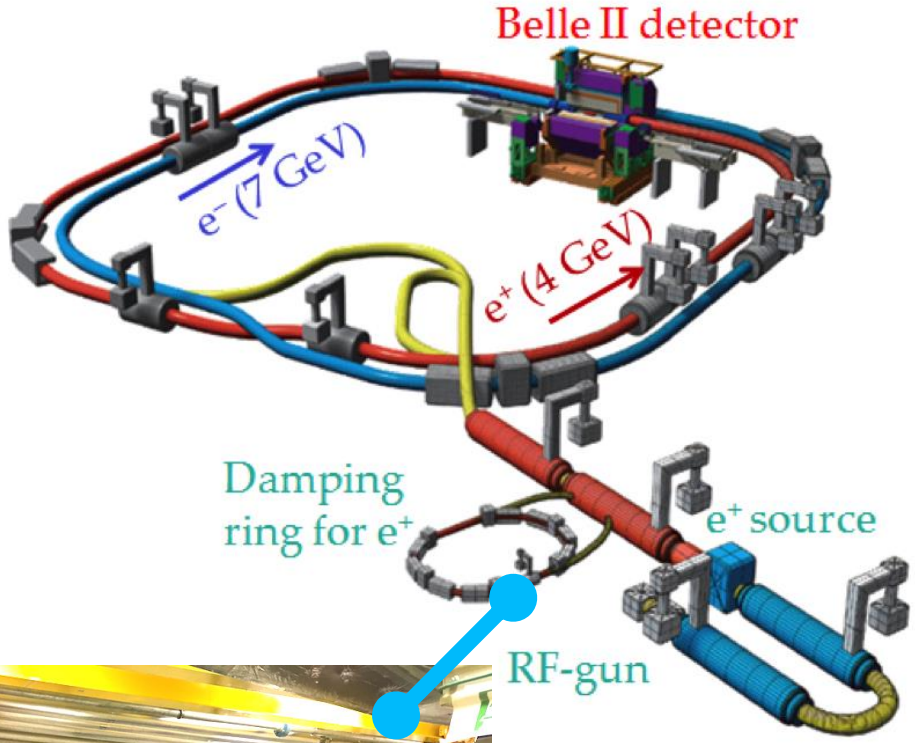
T. Abe

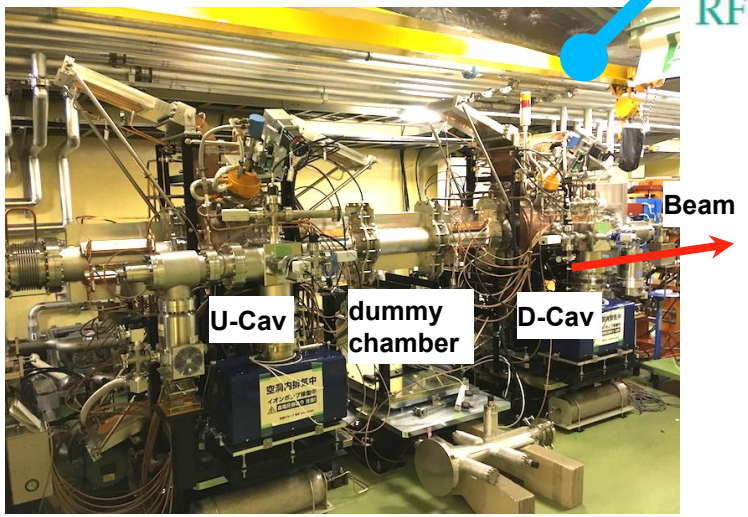


Q_0:~30000, R/Q: 150
Vc = 0.7MV/cav.（Pc=150kW）

3 cavities will be driven by one klystron

In the present plan, two cavies of U- and D-cav. are used for operation; M-cav is omitted, so dummy chamber was installed between the two cavities instead of M-Cav.



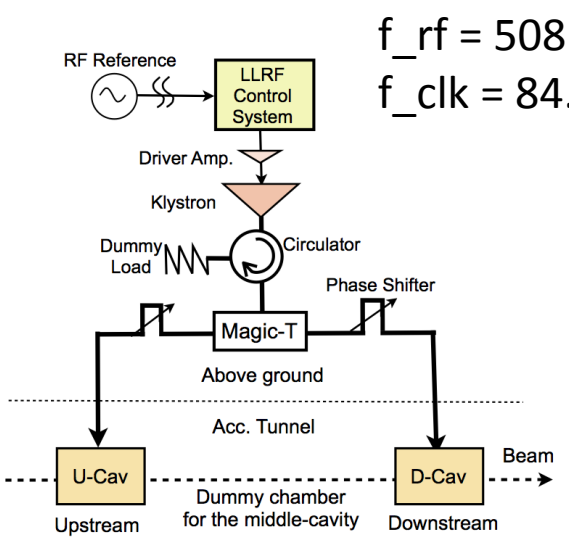


By courtesy of Kobayashi

LLRF Control System for DR

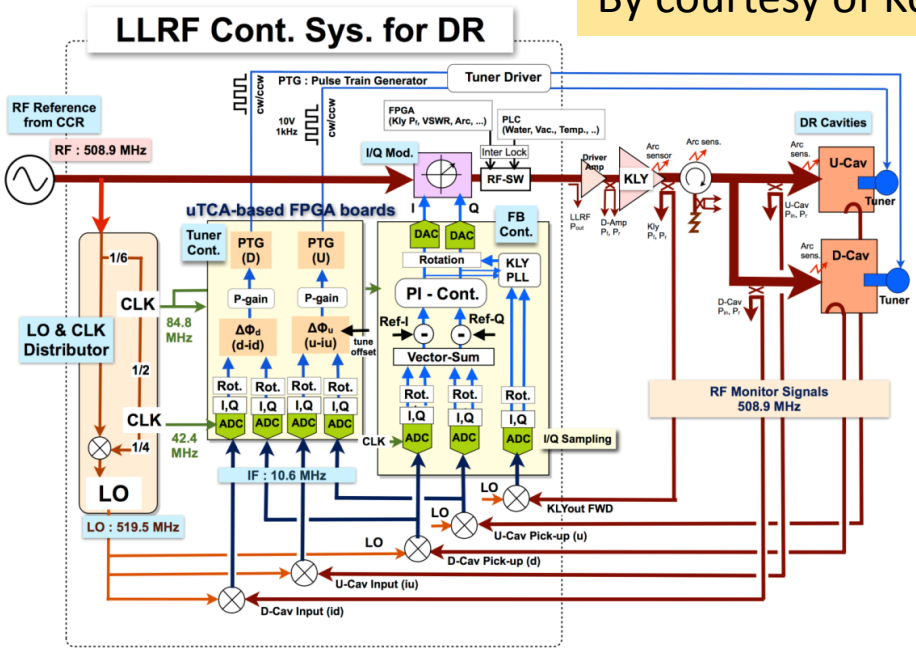
Basically DR-LLRF control system is same as that for MR, except vector sum control of 2 (or 3) cavities.

By courtesy of Kobayashi

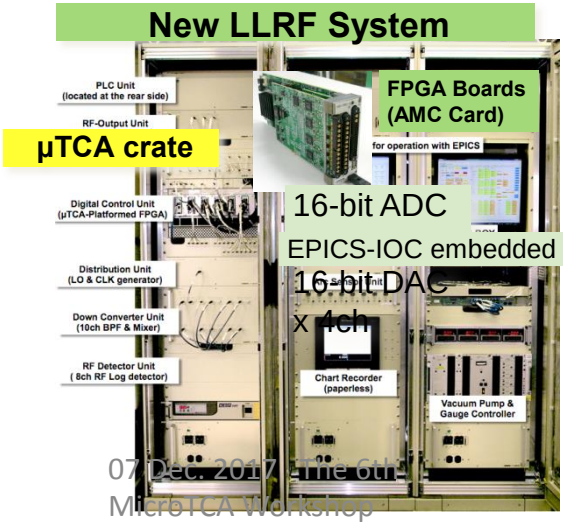


f_rf = 508.9 MHz

f_clk = 84.8 MHz

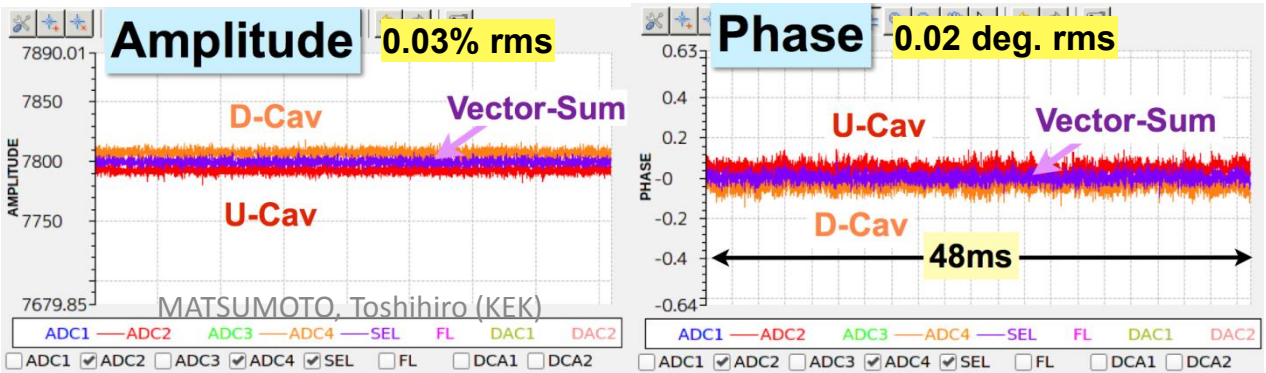


New LLRF System



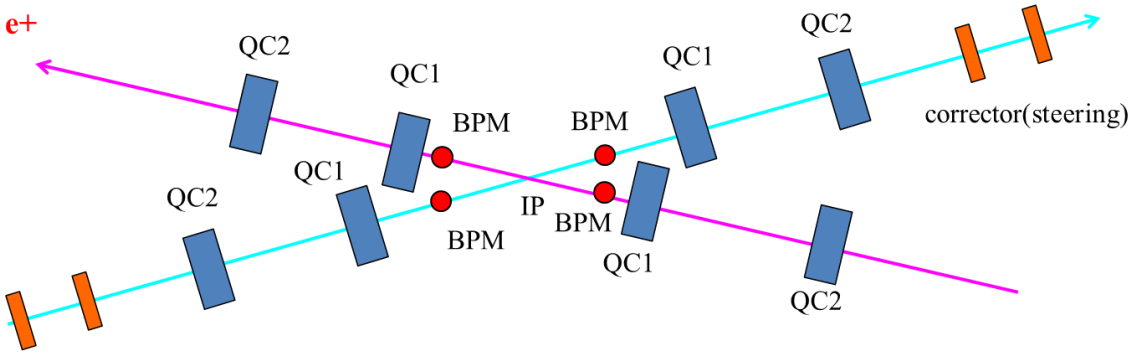
Good performance in vector sum control of the two cavities was demonstrated and conditioning of the cavities was accomplished smoothly in June 2017

Stability of 2-Cav. Vector Sum

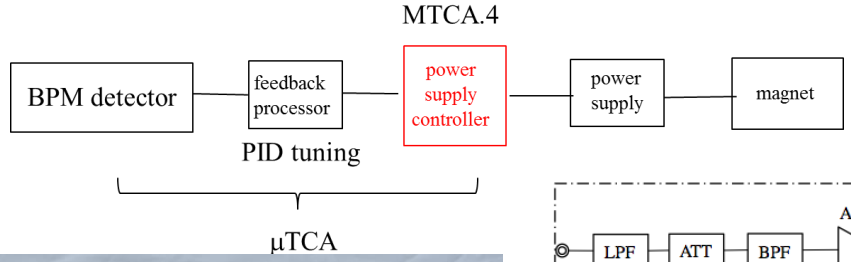


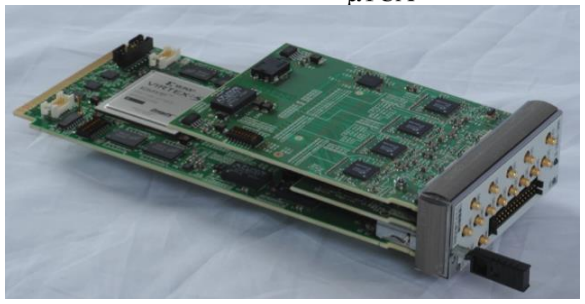
Beam Orbit feedback control at Interaction Point -1-

- Typical vertical rms size at the collision point (IP) is 50 nm.
- Position offset at IP is to be corrected by steering magnets based on data of BPMs near IP in order to maintain stable collision.

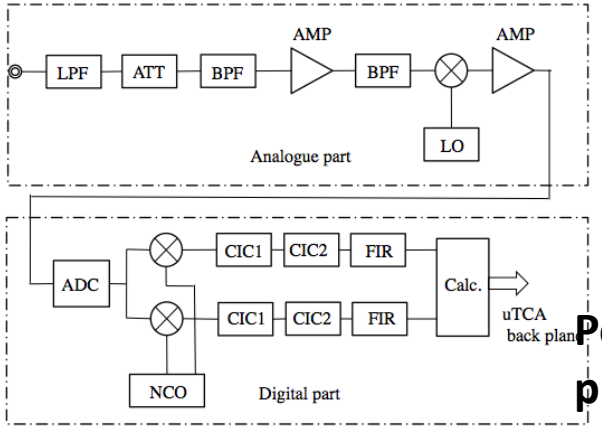


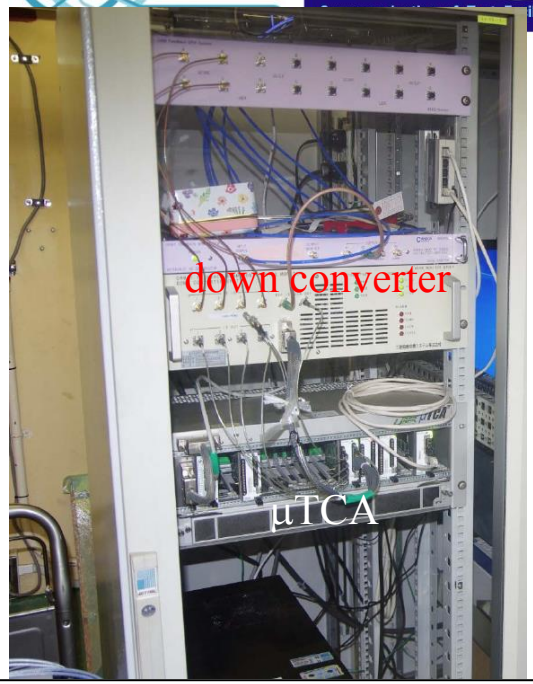
- Orbit Feedback System





Digital processor board (BPM detector)





Down-covert 508.8MHz component to intermediate frequency (IF) of 16.9 MHz with an analog mixer.

AD conversion

Digital filters (2 CICs, 1 FIR)

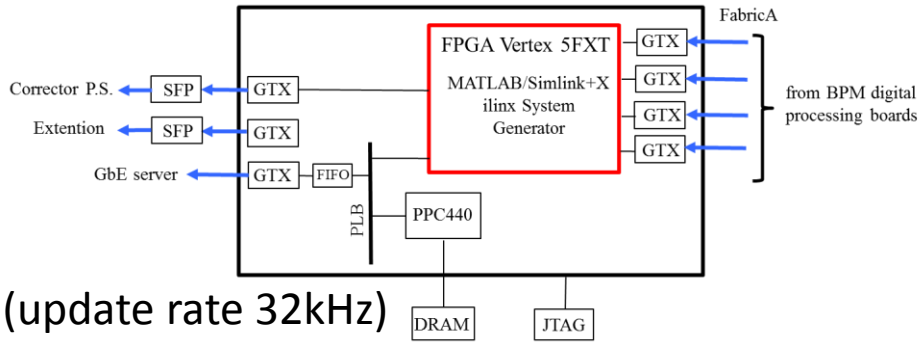
Position calculation

Position data is send to feedback processor via uTCA back plane.

By courtesy of Fukuma

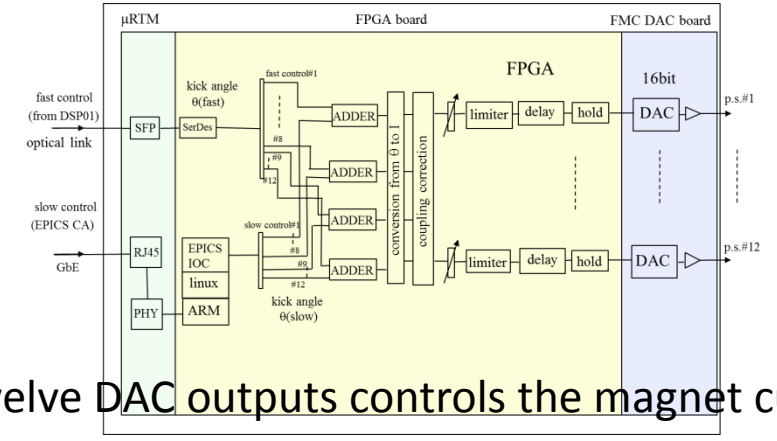
Beam Orbit feedback control at Interaction Point -2-

- Feedback calculation is done in the feedback processor by using data from four BPM detectors.
- The feedback processor board and the power supply controller are connect with optical fiber.
  - Feedback processor



(update rate 32kHz)

  - Power supply controller



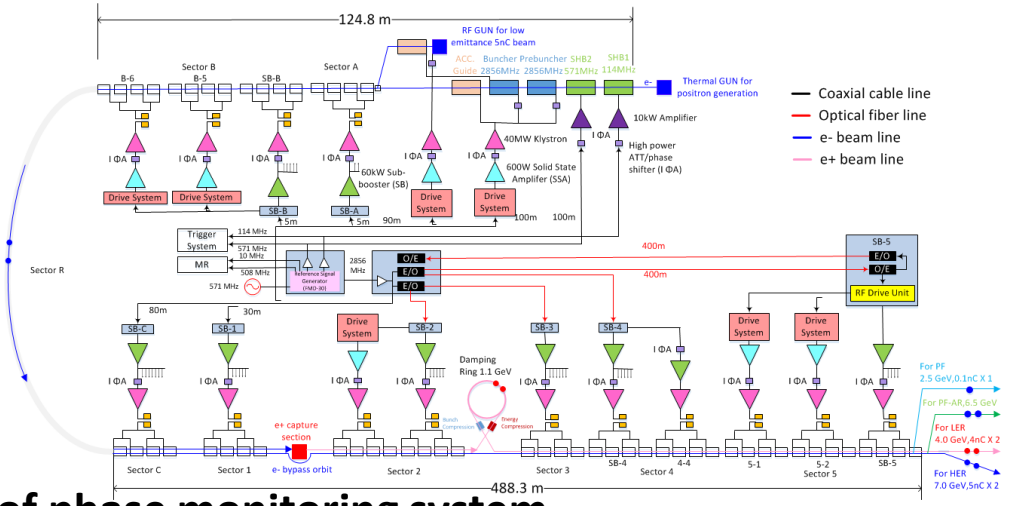
Twelve DAC outputs controls the magnet current.

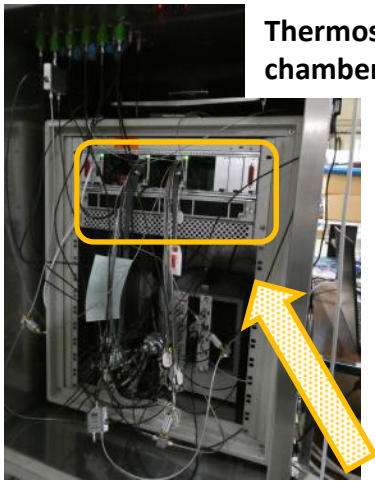
These prototype boards are now under test.

By courtesy of Fukuma

Construction of Phase Monitoring System at SuperKEKB Injector LINAC

- In order to measure the phase stability of RF reference system, the monitoring system that uses the digital board developed by cERL and SuperKEKB was constructed.

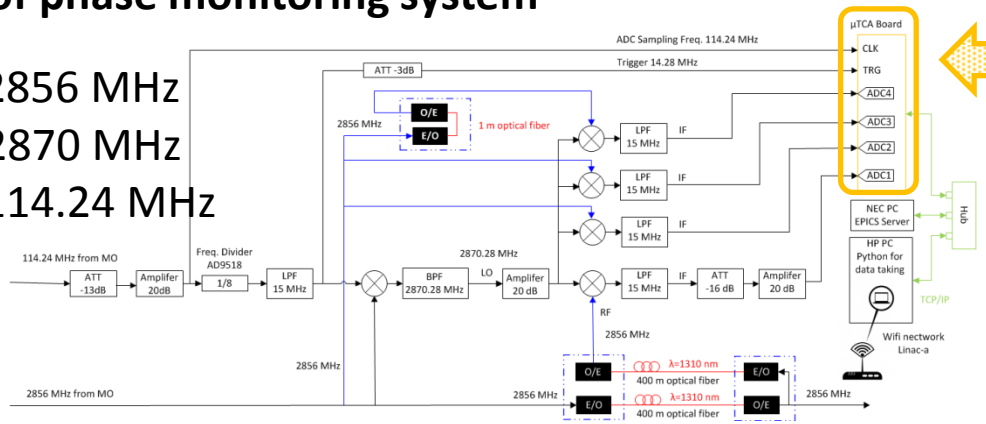


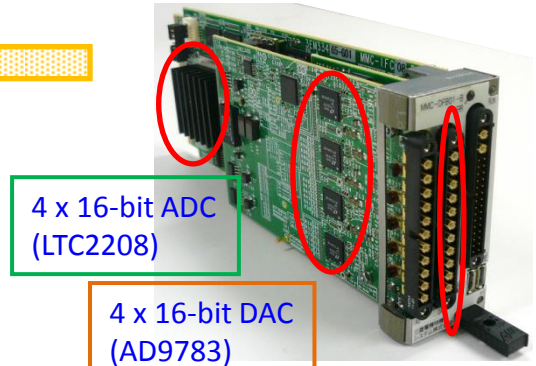


Thermostatic chamber

Setup of phase monitoring system

f_rf = 2856 MHz
F_lo = 2870 MHz
f_clk = 114.24 MHz





4 x 16-bit ADC (LTC2208)

4 x 16-bit DAC (AD9783)

Mitsubishi Electric TOKKI

- In order to stabilize the RF reference system, we proceed with …

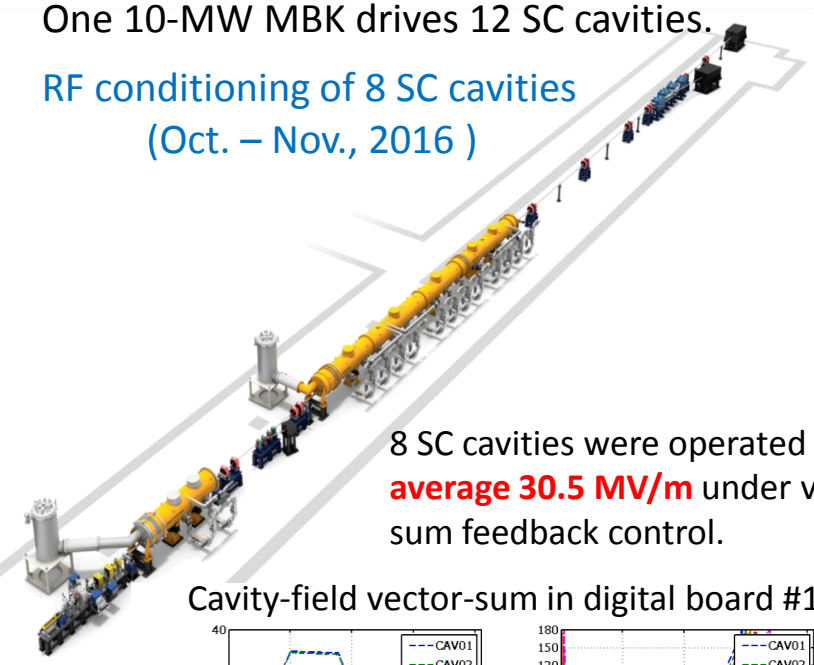
1) Evaluation of phase variation caused by temperature and humidity
2) Installation of feedback system

STF-2 : Prototype of ILC-TDR (2015-)

STF-2: Prototype of ILC-TDR

One 10-MW MBK drives 12 SC cavities.

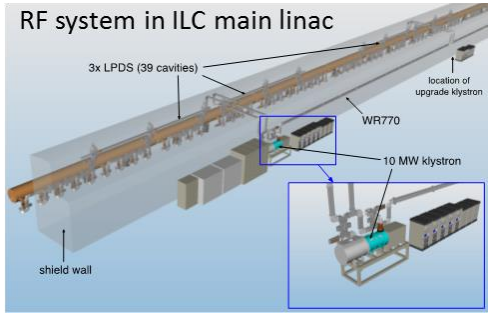
RF conditioning of 8 SC cavities
(Oct. – Nov., 2016)

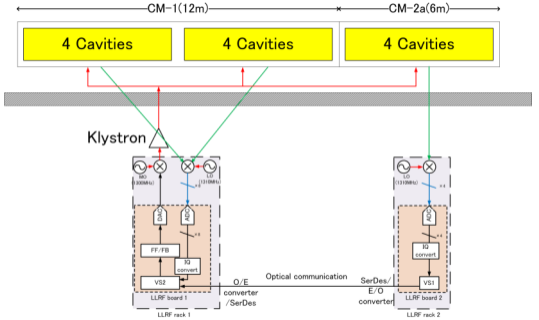


8 SC cavities were operated with **average 30.5 MV/m** under vector-sum feedback control.

- In STF-2, two digital LLRF boards connected with optical communication are configured for operation.

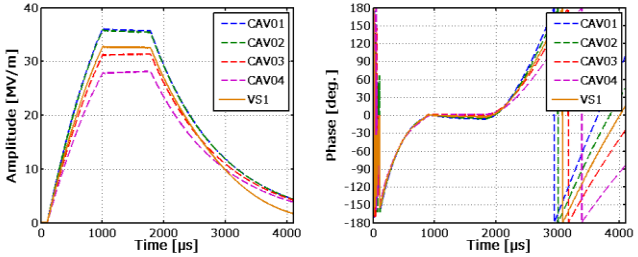
→ minimal combination of ILC LLRF system.



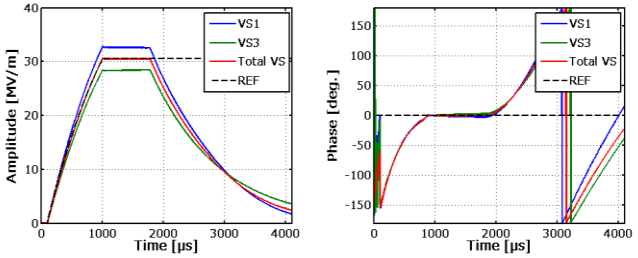


f_{rf} = 1300 MHz
f_{lo} = 1310 MHz
f_{clk} = 81.25 MHz

Cavity-field vector-sum in digital board #1

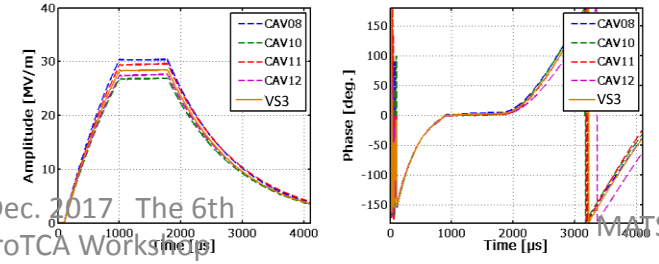


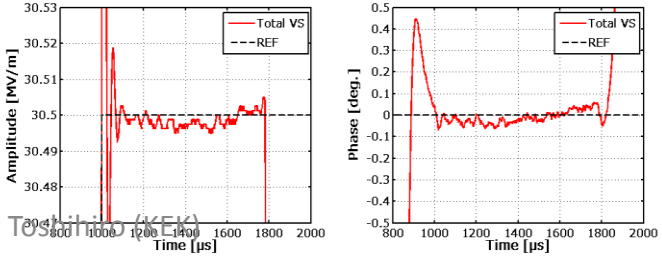
VS1



VS3

Cavity-field vector-sum in digital board #2



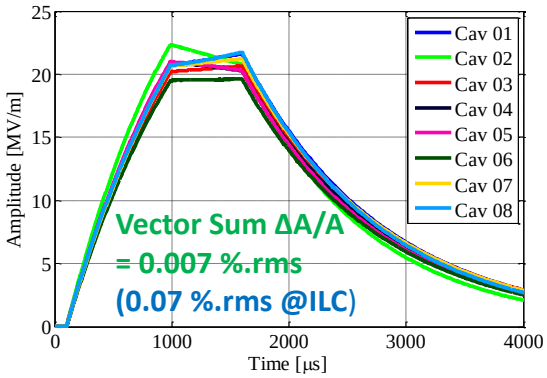


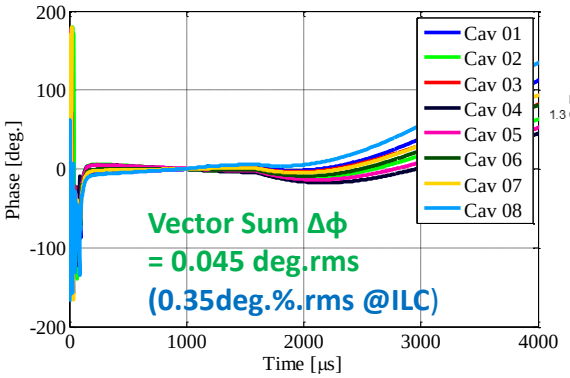
ΔA/A =0.006%rms (0.07%@ILC)

Δφ = 0.03deg.rms (0.35deg.@ILC)

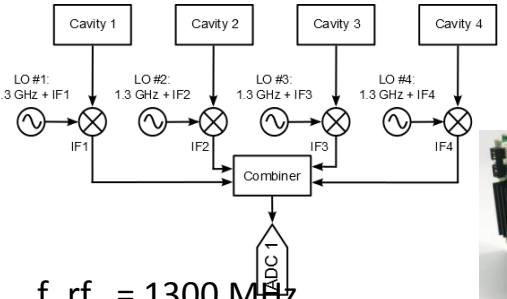
Technological Development and Research at STF

IF Mixture Performance





IF-mixture Technique



f_rf = 1300 MHz
f_clk = 81.25 MHz

MitsubishiElectric TOKKI

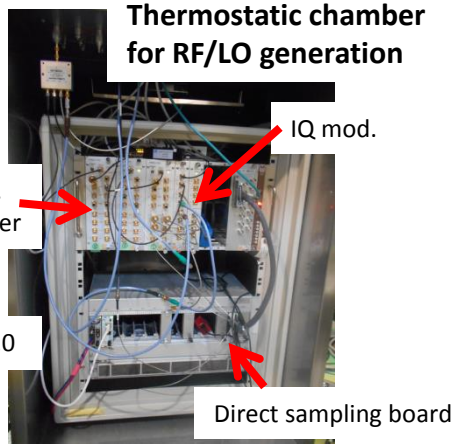
By using IF signal with different frequencies, 8 SC cavities are operated with 2 ADCs.
The measured performance fulfilled the ILC stability requirement.

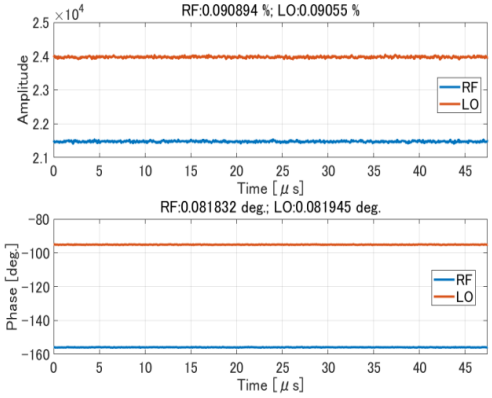
SIMULTANEOUS MEASUREMENT OF RF AND LO SIGNAL

By using direct sampling technique, RF signal and LO signal are measured simultaneously.

Mitsubishi Electric TOKKI
2 ADCs (ADS5474)

f_rf = 1300 MHz
f_lo = 1310 MHz
f_clk = 172 MHz





RF and LO signals :
ΔA/A = 0.09 %.rms
Δϕ = 0.08 deg.rms

By adopting a filter, improvement of accuracy can be expected.

In order to stabilize the RF reference system, the feedback control system will be installed.

Summary

- At KEK, LLRF control systems using MicroTCA standard have been developed for common-use hardware in SuperKEKB, STF and cERL.

- KEKB Ring

- In Damping Ring, new LLRF system was installed and two cavities vector sum feedback control was demonstrated with good performance.
- The beam orbit FB control system at the collision point was development by using MTCA.0 and MTCA.4 standard. It is now under evaluation.

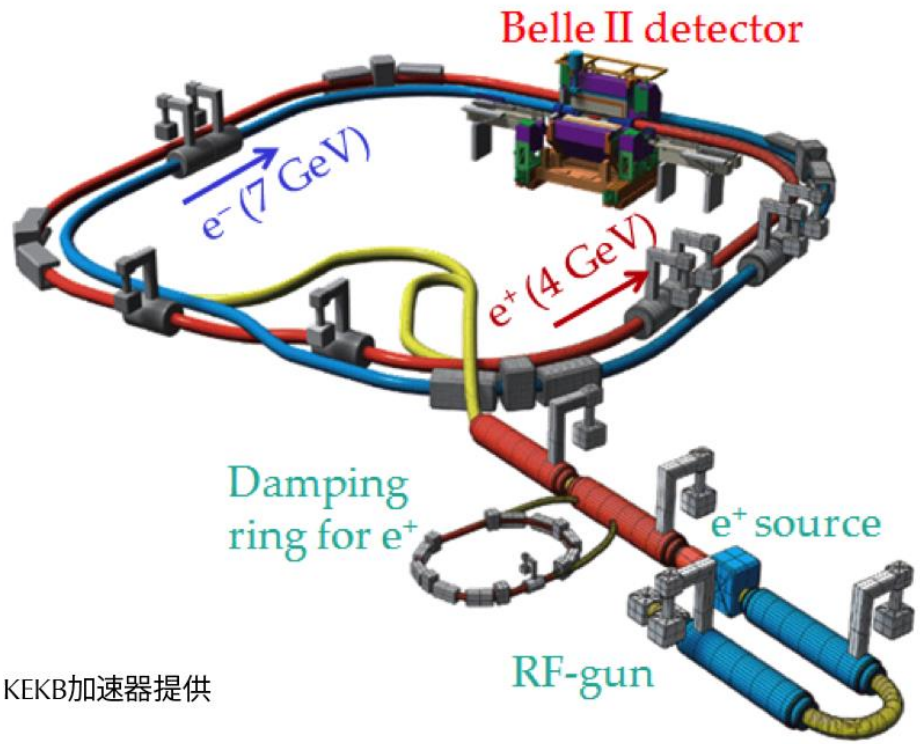
- KEKB Linac

- Phase monitoring for the RF reference system was constructed. In order to stabilize the RF reference system, the feedback control system will be installed.

- STF

- The minimal combination of ILC LLRF system by using two digital boards was demonstrated.
- IF mixture feedback control and phase monitoring of RF reference line were evaluated.

Thank you for your attention!



KEKB加速器提供