Current Status of PAL-XFEL Project

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@ LINAC2014, Geneva

In Soo Ko
on behalf of PAL-XFEL team

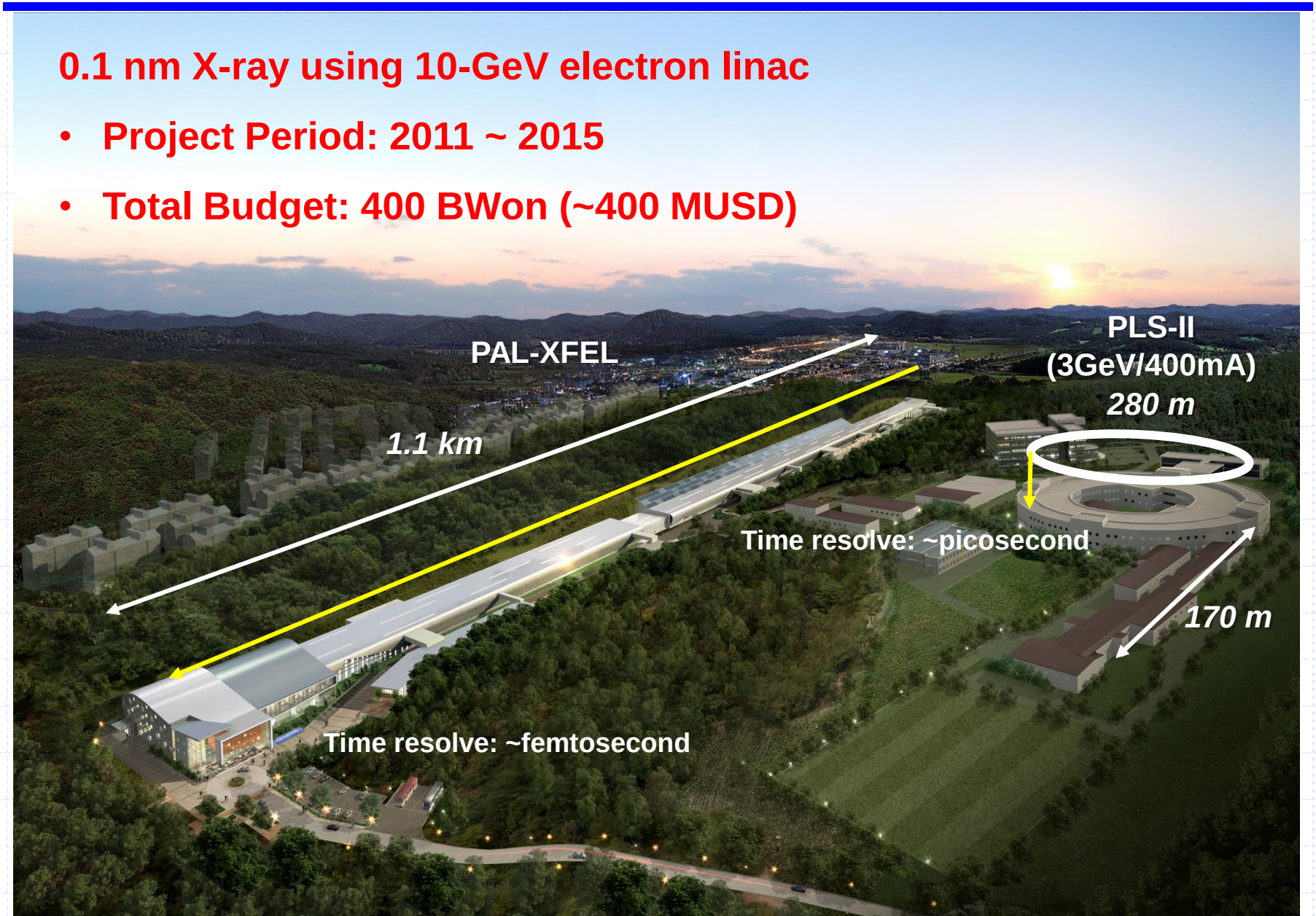
Contents

- Brief Overview of PAL-XFEL Project
- Site Preparation and Building Construction
- Injector Test Facility
- Development of Key Technologies with Domestic Companies
- Summary

Overview of PAL-XFEL

0.1 nm X-ray using 10-GeV electron linac

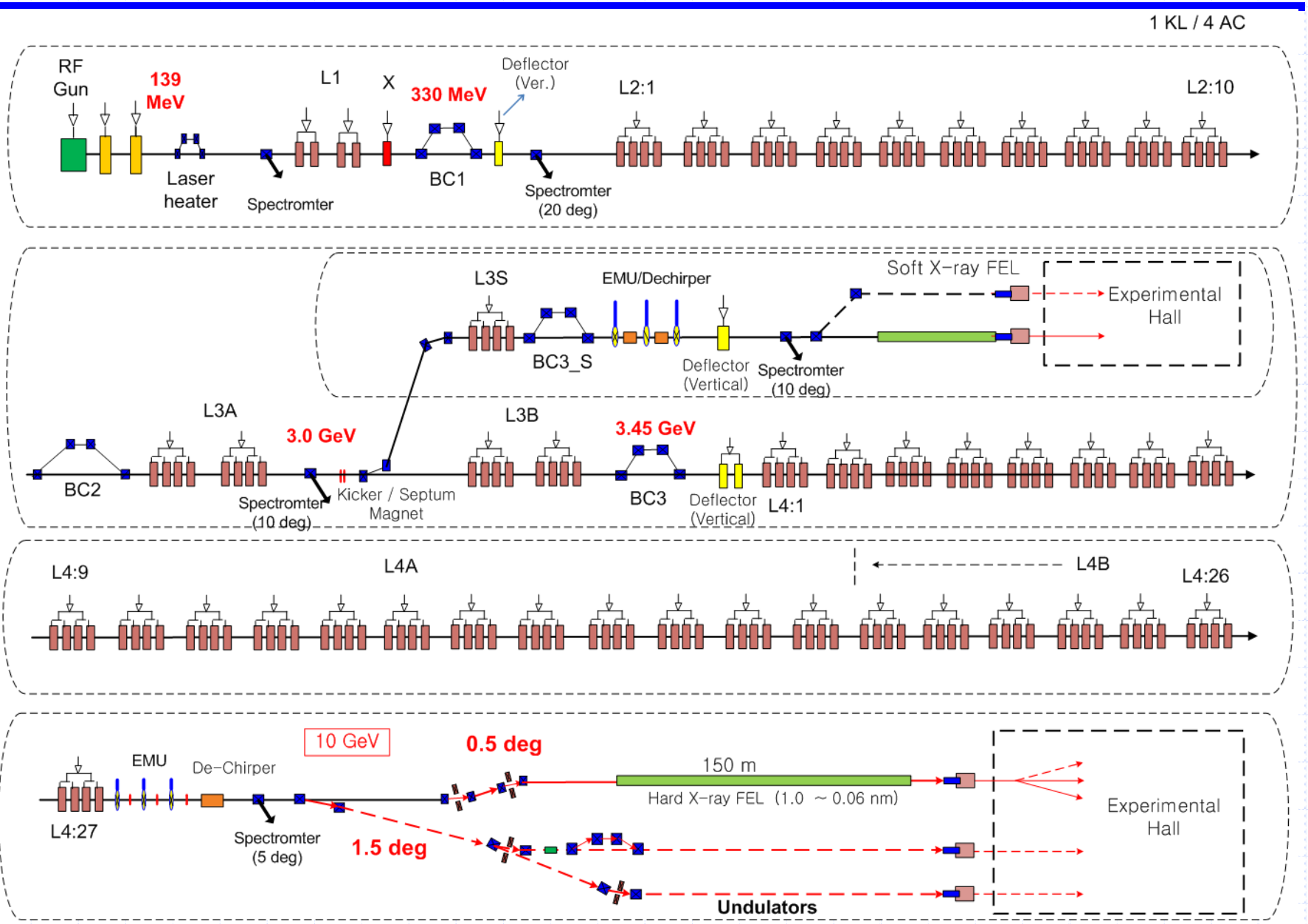
- **Project Period: 2011 ~ 2015**
- **Total Budget: 400 BWon (~400 MUSD)**



Technical Outline

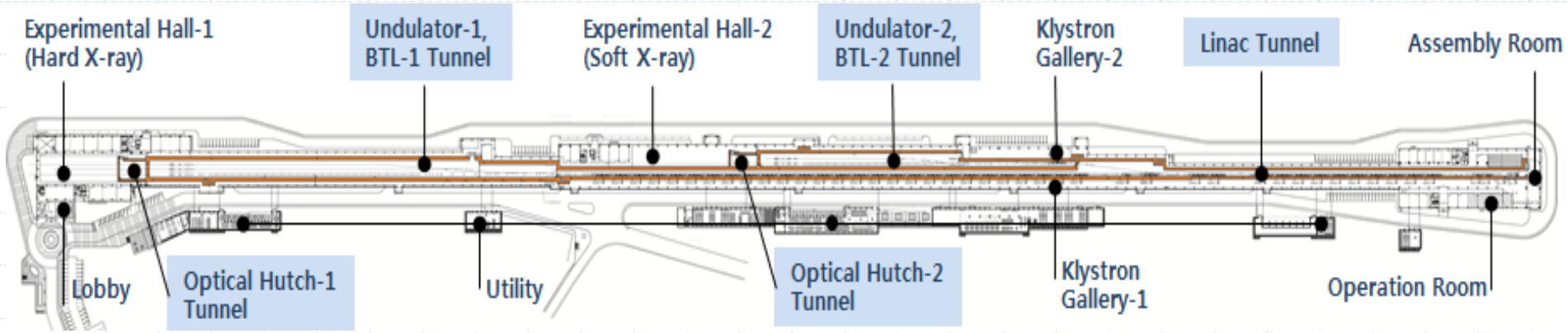
- 10-GeV linac
  - Phothocathode RF gun (Cu)
  - S-band normal conducting structure and X-band linearizer
  - 60 Hz repetition rate
- Undulators
  - Out-vacuum (HXU period: 26 mm, SXU: 34 mm)
  - Variable gap (XHU/SXU minimum 8.3 mm)
  - 0.1 nm (HX) / 1~3 nm (SX)
  - Space for 3 HX undulators and 2 SX undulators
- Separate experiment spaces for HX and SX
- Experiments in the first stage (chosen by Korean users)
  - Hard X-ray Pump-and-Probe
  - Hard X-ray Coherent Imaging
  - Soft X-ray Pump-and-Probe
- Maximum use of domestic industries

XFEL Layout


1 KL / 4 AC
RF Gun
139 MeV
L1
X
330 MeV
Deflector (Ver.)
L2:1
L2:10
Laser heater
Spectromter
BC1
Spectromter (20 deg)
L3S
EMU/Dechirper
Soft X-ray FEL
Experimental Hall
BC3_S
Deflector (Vertical)
Spectromter (10 deg)
L3A
3.0 GeV
L3B
3.45 GeV
BC2
Spectromter (10 deg)
Kicker / Septum Magnet
BC3
Deflector (Vertical)
L4:1
L4:9
L4A
L4B
L4:26
10 GeV
0.5 deg
EMU
De-Chirper
150 m
Hard X-ray FEL (1.0 ~ 0.06 nm)
L4:27
Spectromter (5 deg)
1.5 deg
Undulators
Experimental Hall

General Layout of Building

- Total Length: 1,110 m
- Total Floor Area: ~40,000 m^2
- Building placed on the rock base mostly
- Soft ground replace with massive concrete (No pile used)
- Utility buildings separately located from the accelerator building by two-lane road
- Shielding: 2-m thick concrete



Site Preparation and Building Construction

Aerial View of PAL (July 2012)

Aerial View of PAL (Dec. 27, 2012)

Aerial View of PAL (May 30, 2013)

Aerial View of PAL (Nov. 22, 2013)

Aerial View of PAL (Feb. 20, 2014)

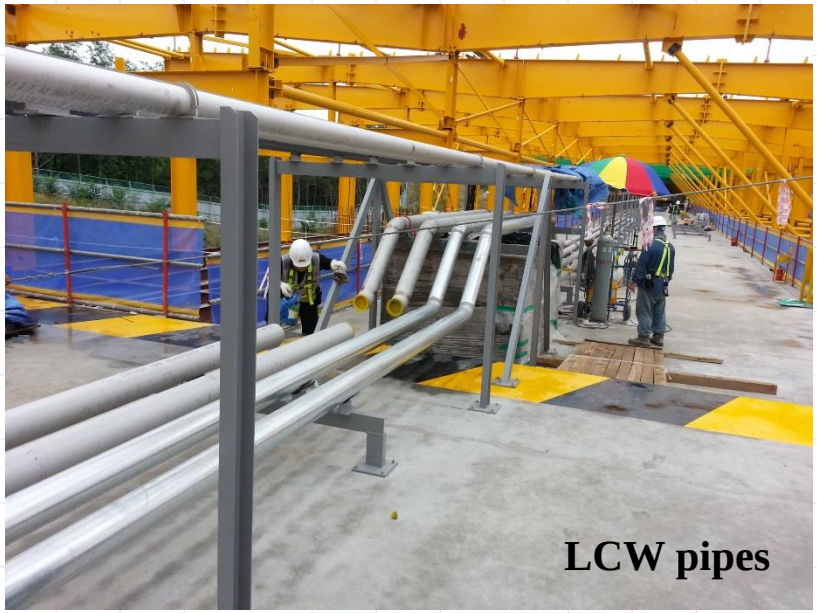
Aerial View of PAL (July 23, 2014)

Ground Preparation (2013. 6. 10)

Site seen on Aug. 29, 2014

WebGuard
2014-08-29 09:08:00
포항 가속기연구소
1.0x P
2014-08-29 09:36:52

Main Building

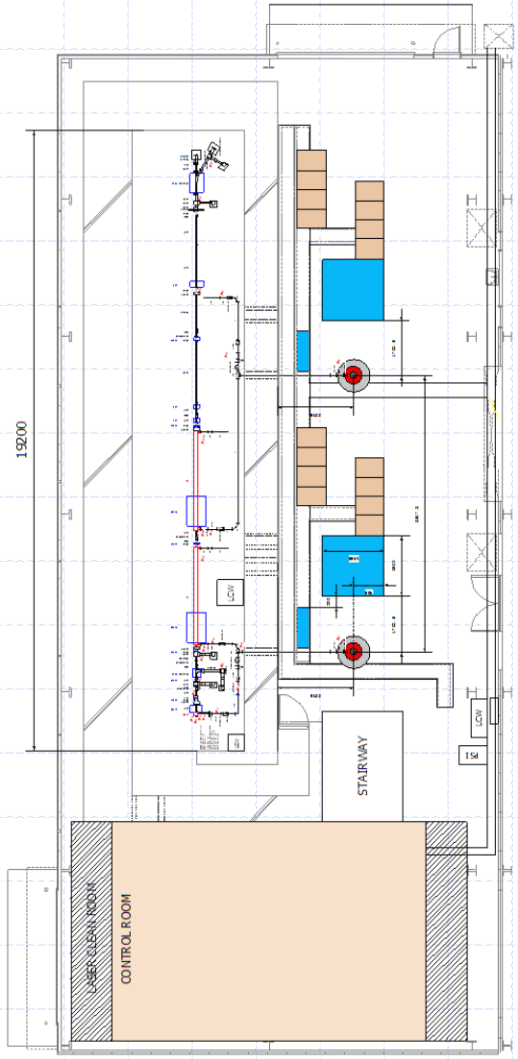

LCW pipes

Undulator tunnel

Linal tunnel

Injector Test Facility

Location of Test Facilities

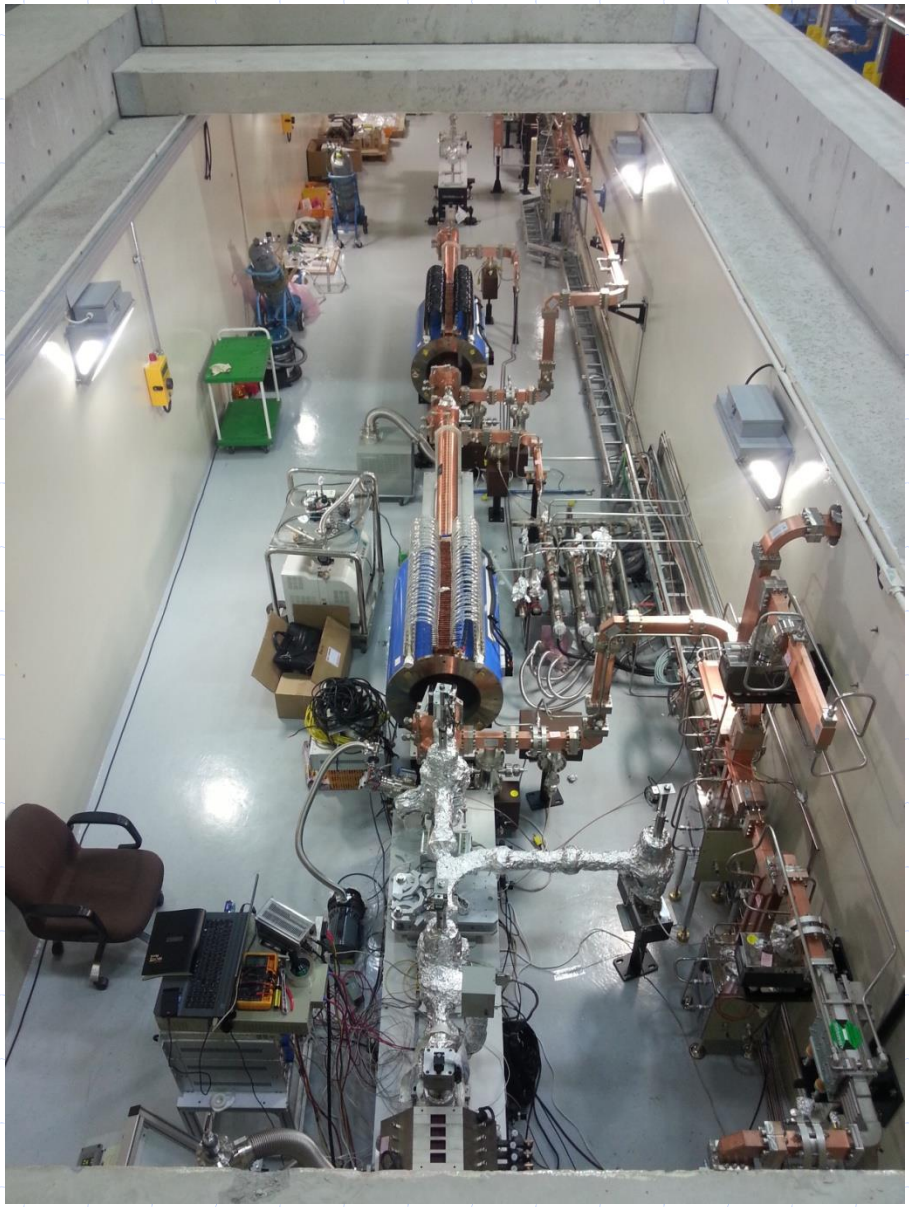


ITF

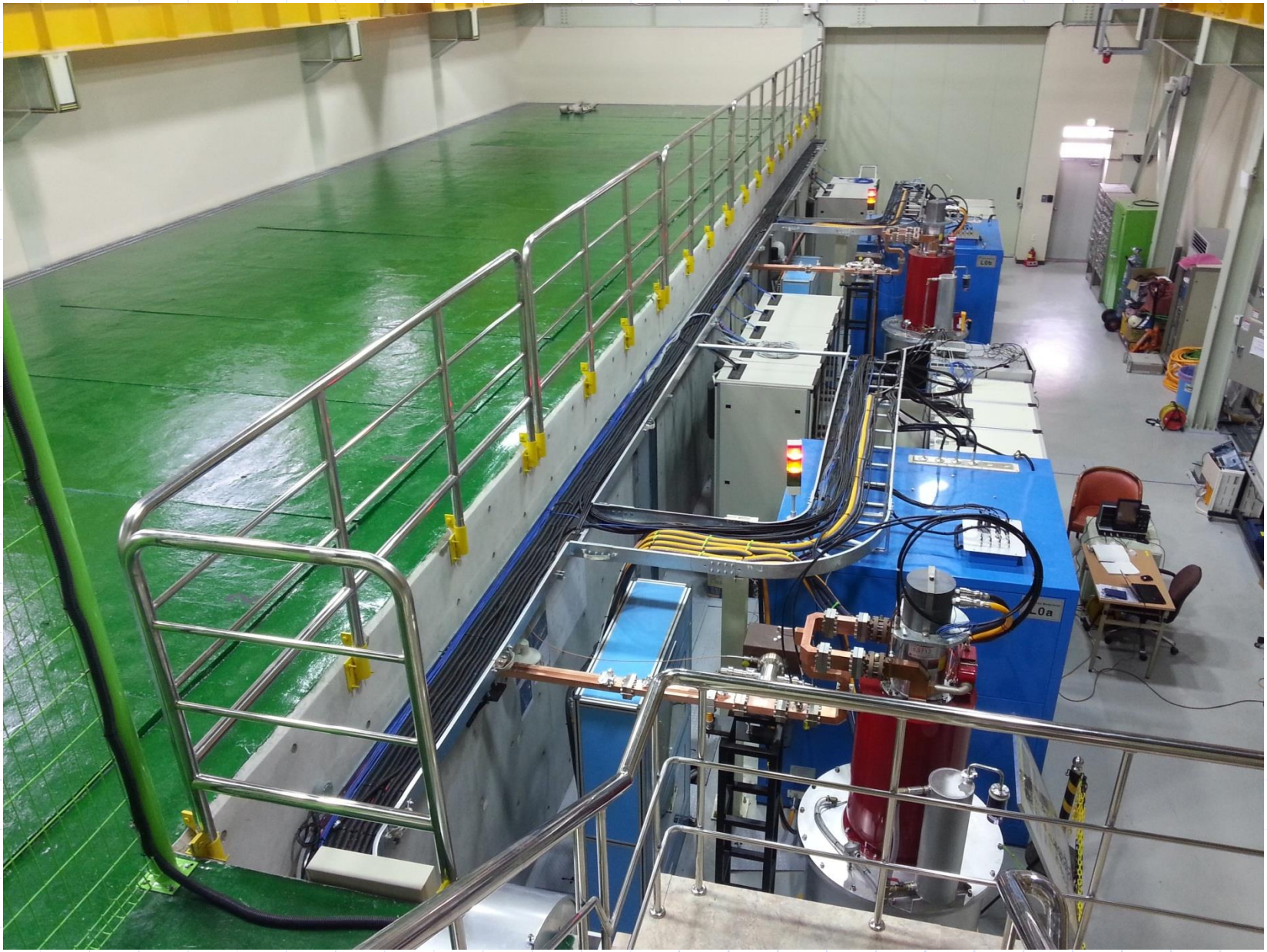
PTF

ATF

ITF as of Oct. 13, 2012

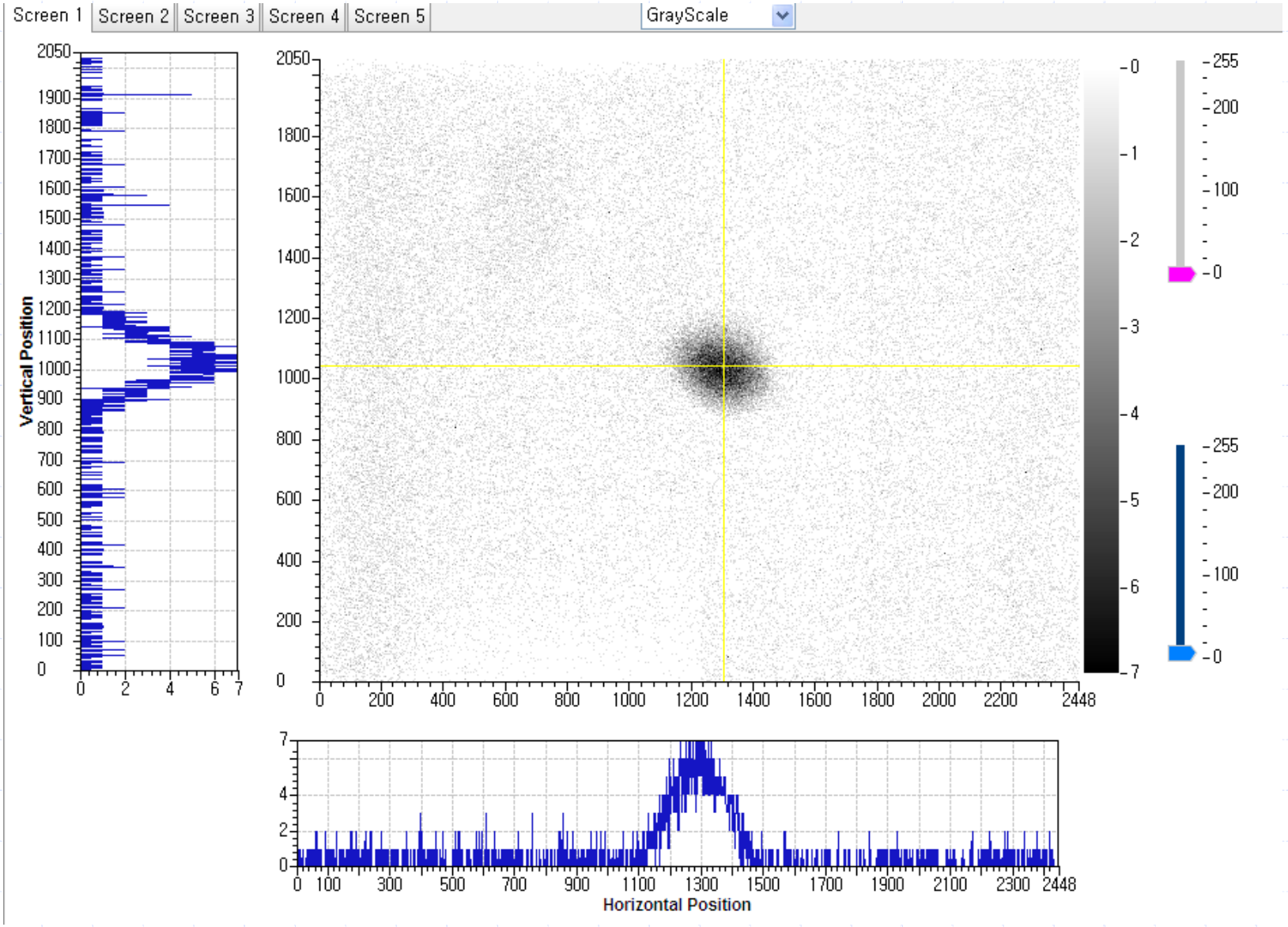


ITF as of Dec. 1, 2012

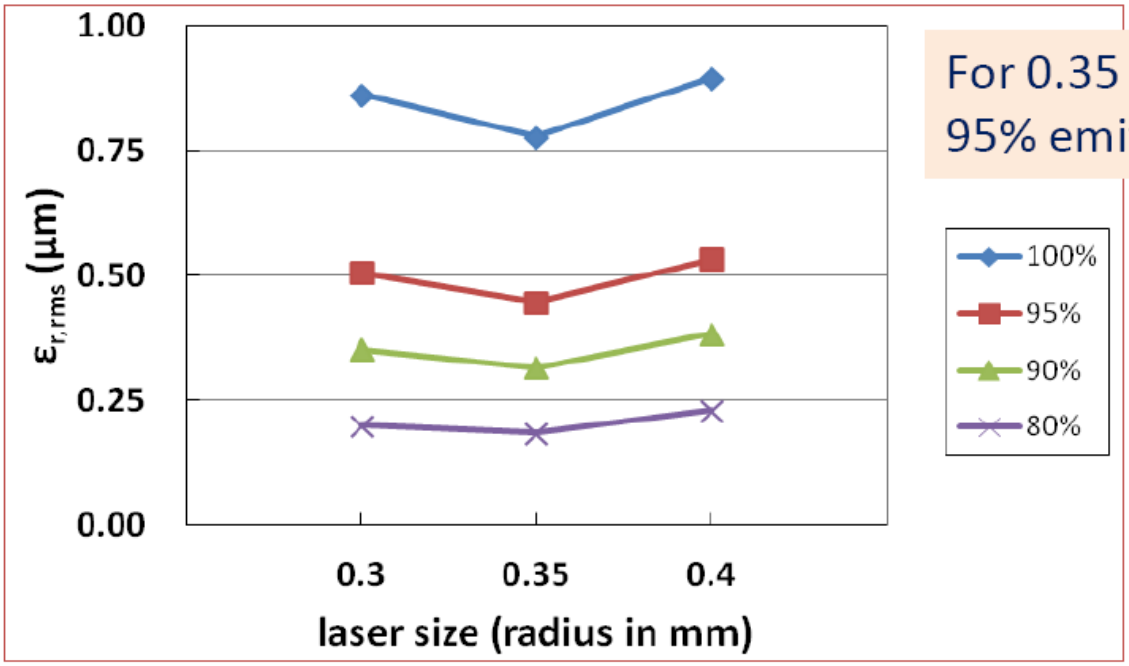


LLRF installed in ITF

Beam on Screen (Dec. 7, 2012)

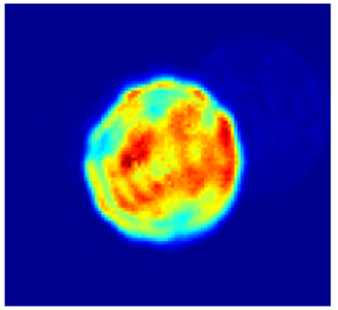


First result from ITF



For 0.35 mm laser size (full radius)
95% emittance: 0.41 / 0.48 μm in X / Y

Laser beam profile



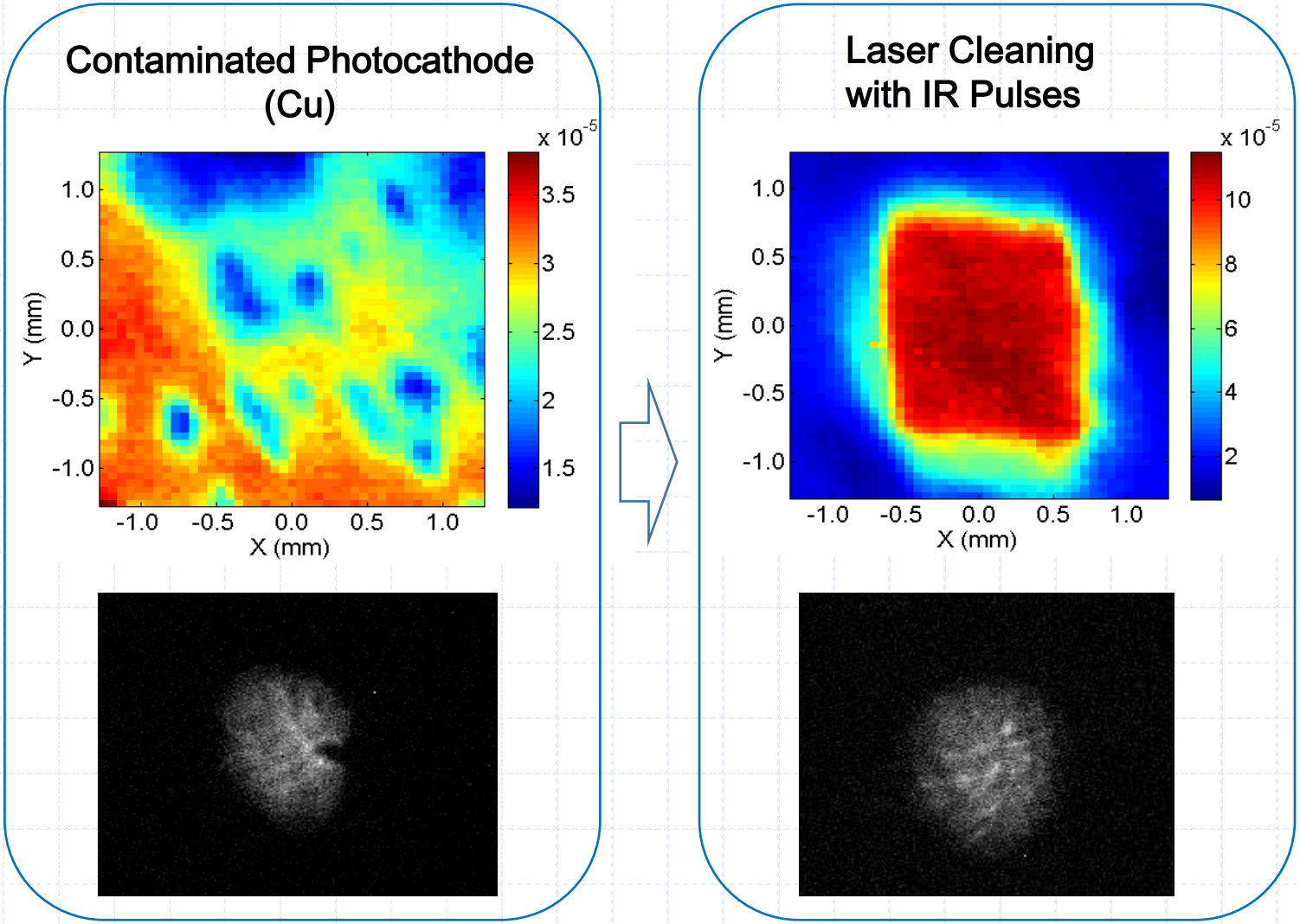
parameter	Value
Beam energy	135 MeV
charge	200 pC
Gun phase (laser injection)	35 degs
Accelerating column phase	on-crest (both)

QE Recovery of Photocathode Gun

IR laser cleaning improves both QE and beam profiles.

QE Maps

E-beam Image at 200 pC



Development of Key Technologies with Domestic Companies

Modulator

LLRF: PAD/PAC and SSA

Undulators and Field Measurement System

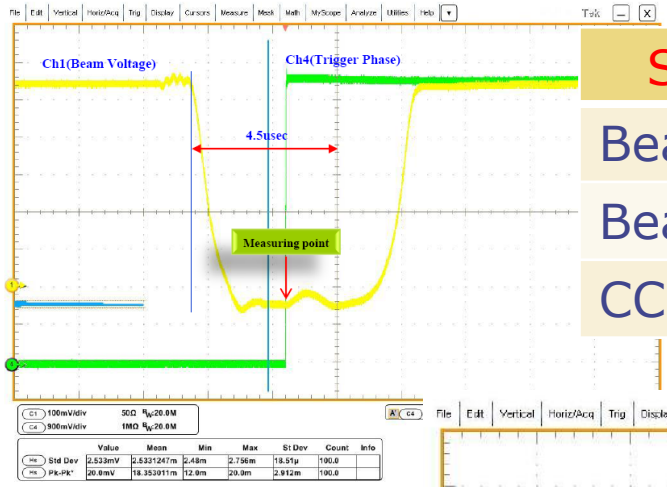
ID Vacuum Chamber

X-band Cavity BPM (with SLAC)

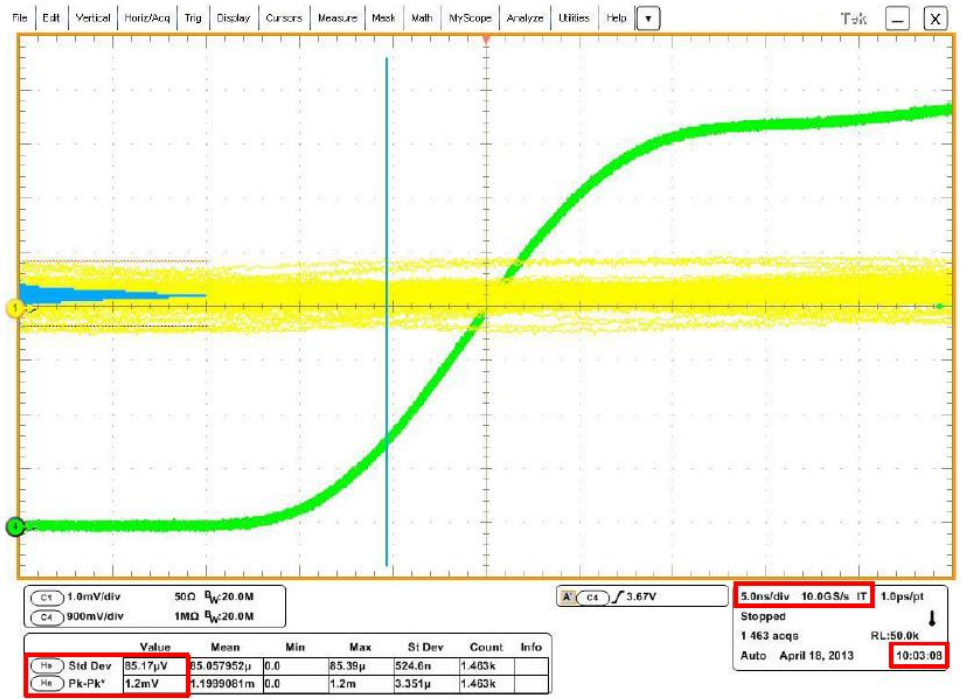
Modulator

Test Results

- **Measuring Point of Beam Voltage**
  - **Sensing cable specification : SUHNER사, S-40462, RS223 type, 50Ω, length = 10m)**
  - **Beam Voltage Phase**



Stability (ppm)	A-Company	B-Company
Beam Voltage	29.61	19.8
Beam Current	38.78	38.85
CCPS (PFN Voltage)	9.05	7.43



PFN Voltage : 42 [kV]

Persistence time : 3 [min]

Repetition Rate : 60 [Hz]

Trigger Thyratron : Synchronized

DA1855A : -39.554[V], ÷10

Standard deviation : 85.17 [µV]

Peak Voltage : 1.20 [mV]

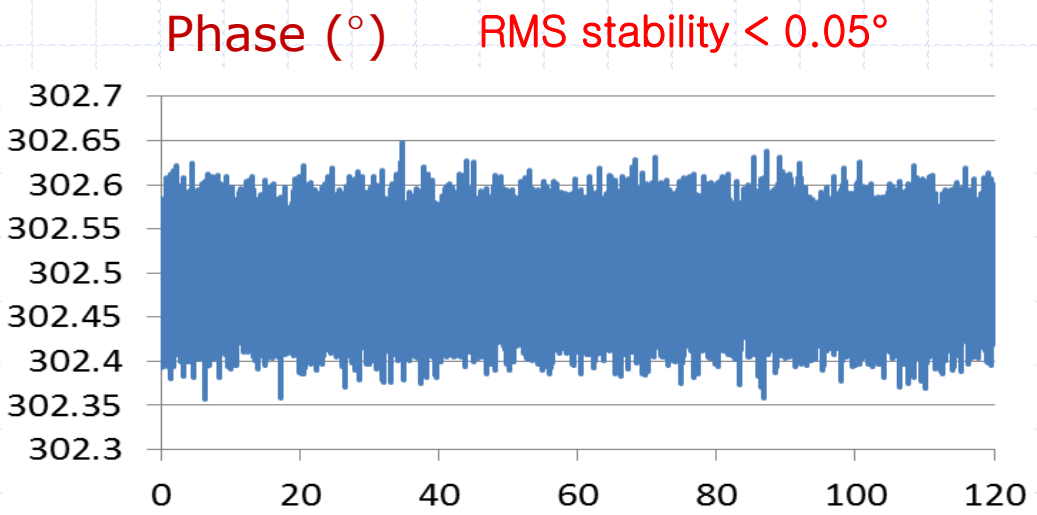
Output Stability :

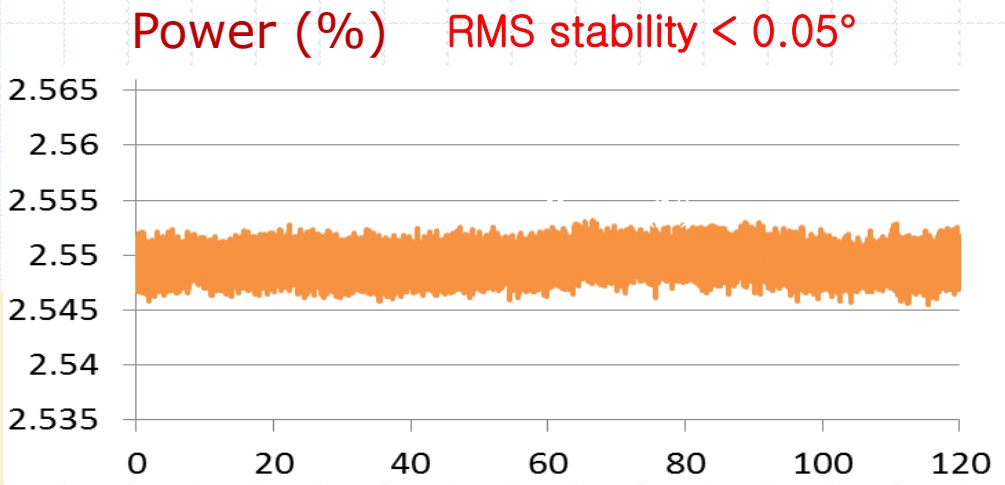
85.17/39.554 = 21.53 [ppm]

Peak Stability :

1200.0/39.554 = 303.38 [ppm]

LLRF: PAD/PAC (prototype)



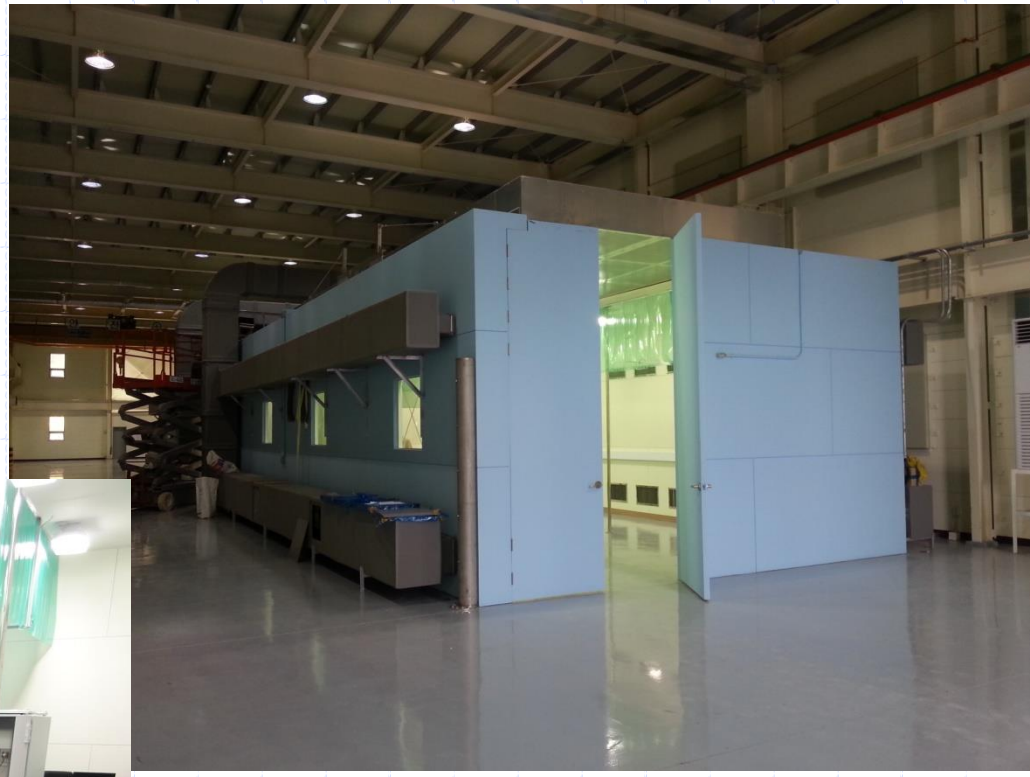


Stability is less than 0.05% and 0.05° for 120 min.

1.2 kW S-band SSA: passed with same tolerance in phase and power

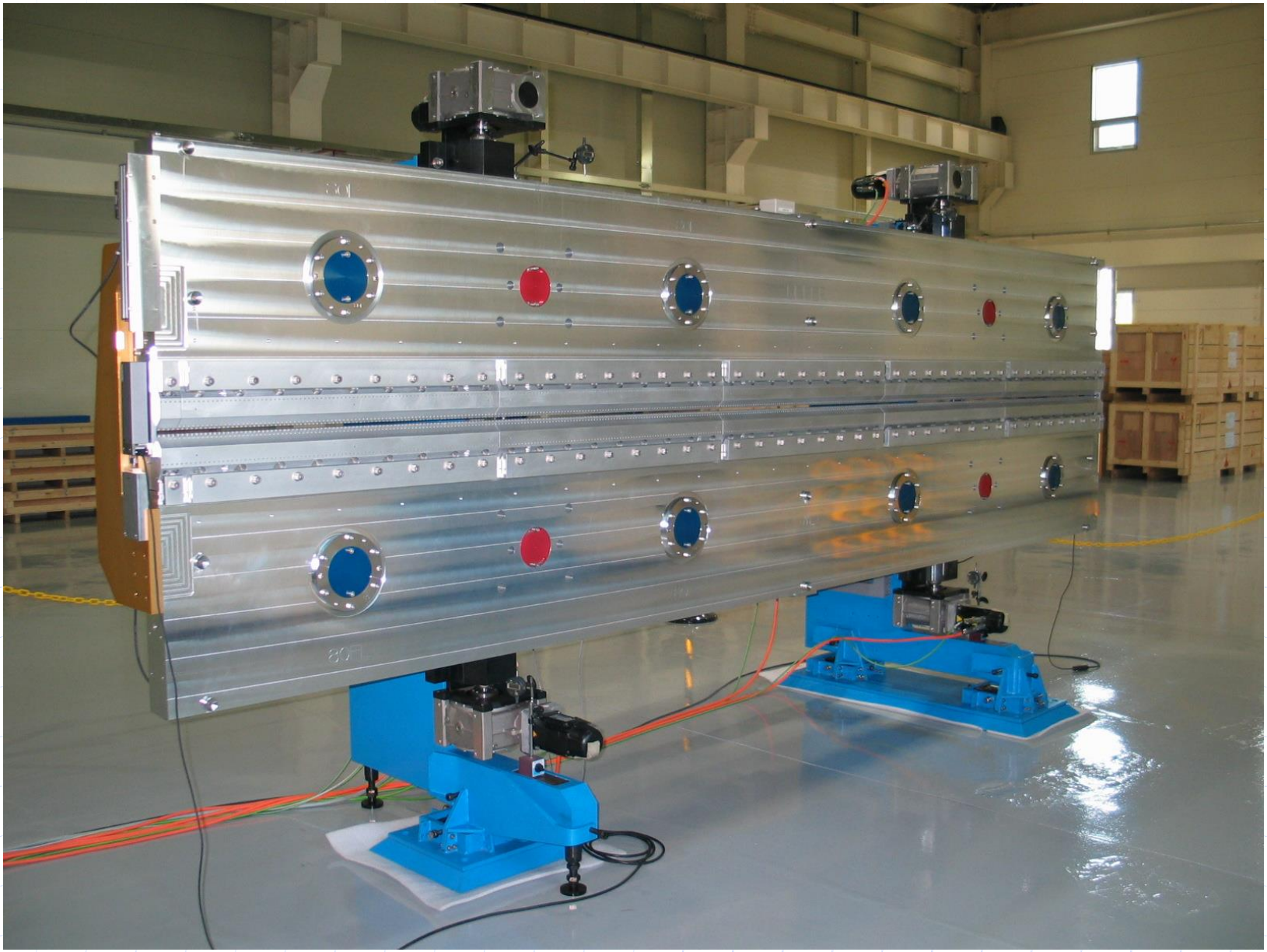
ID Field Measurement Lab

Temperature Stability:
25+/- 0.1°C

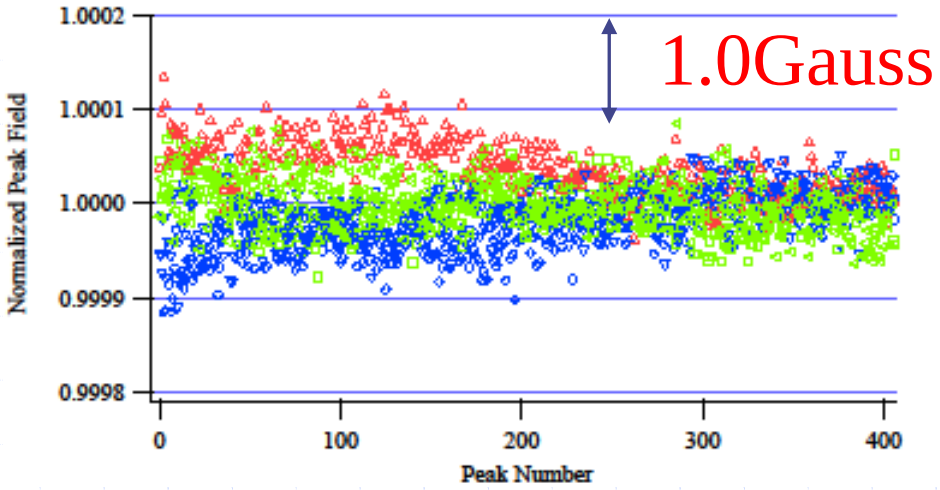


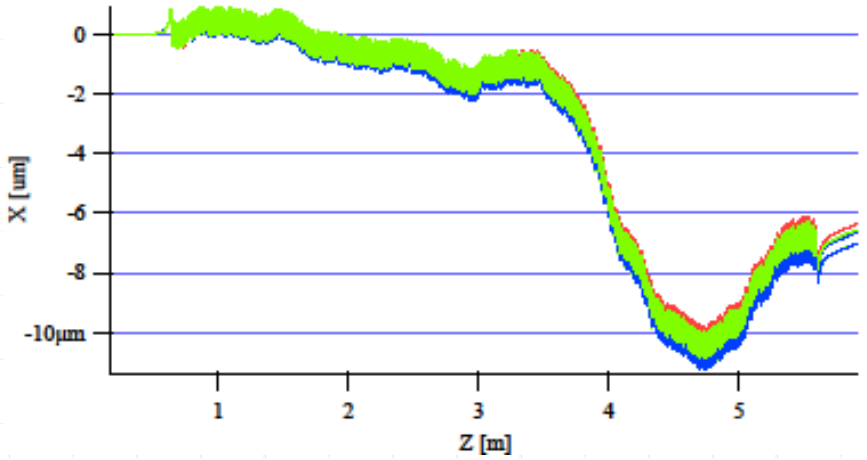
Real Undulator Hall:
250 m (L) x 14 m (W) x 4 m (H)

Prototype Undulator with Magnet



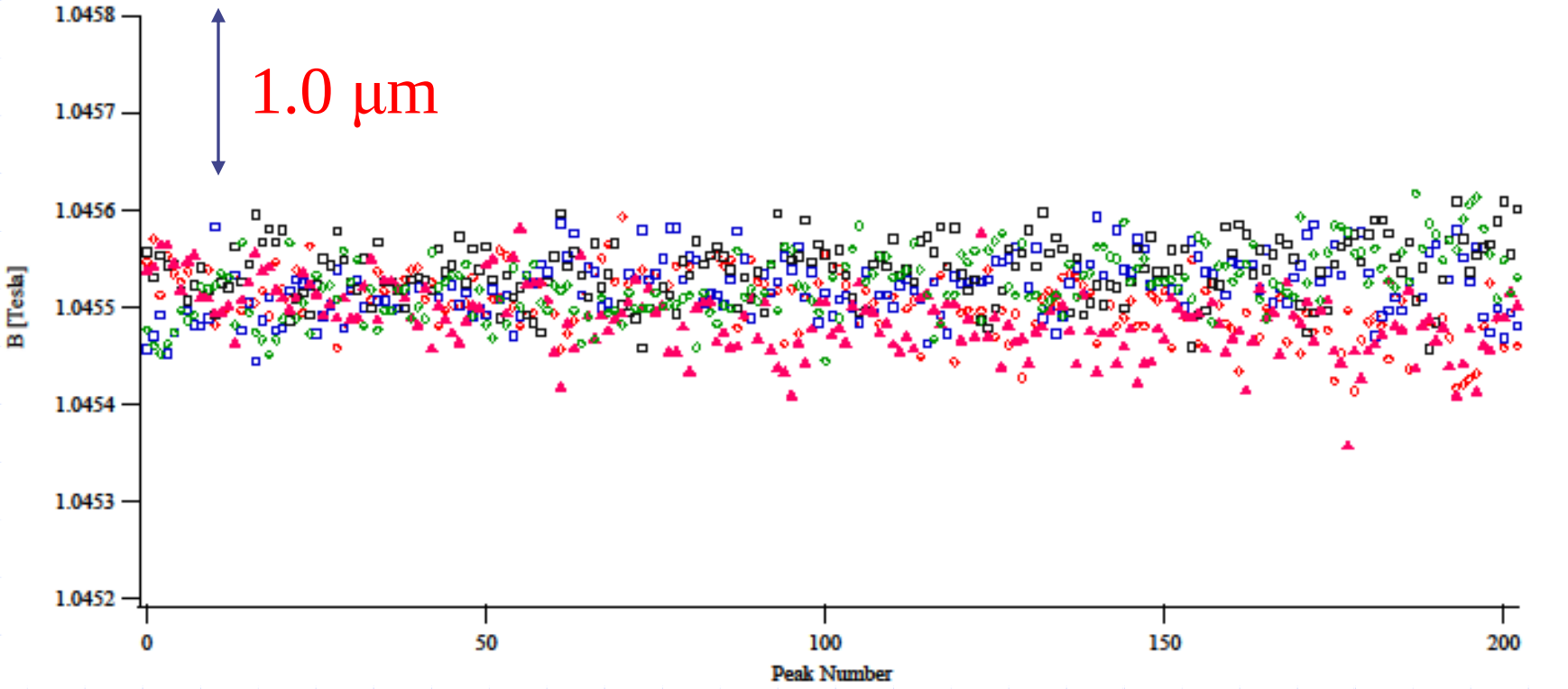
Measurement Errors





- The peak fields from 5 measurements are overlapped.
- B errors are about +/-1.0 G.
- Orbit error from the measurements is less than 1 um.

Gap Reproducibility Errors



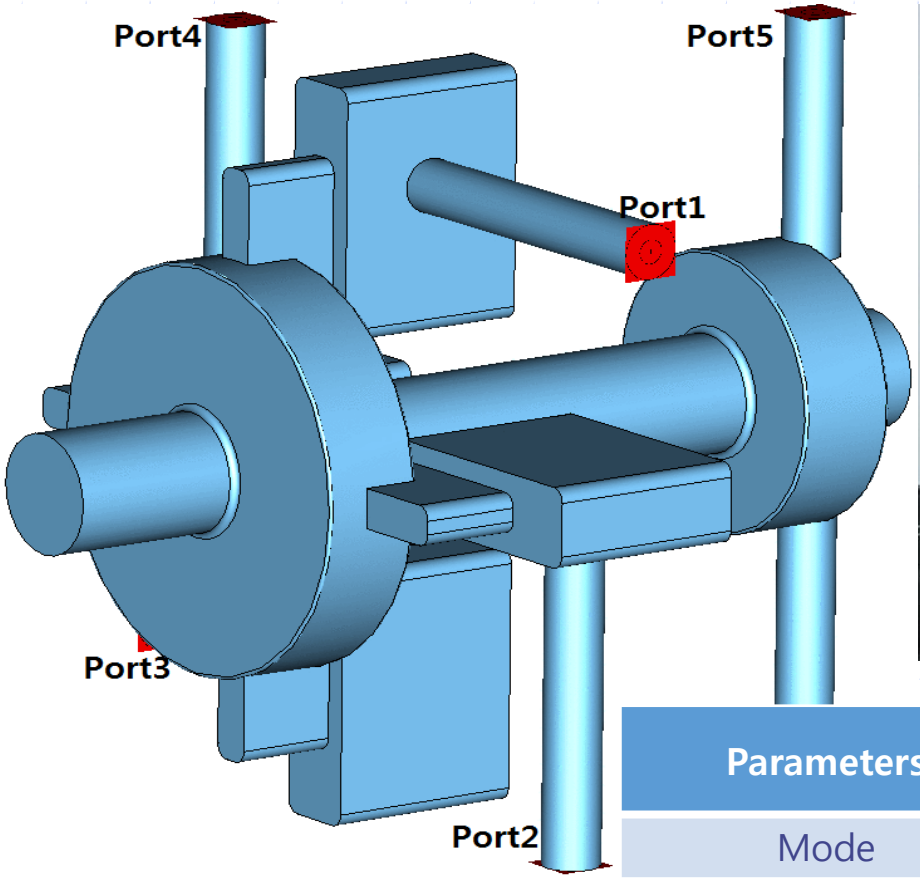
- The peak fields from 5 measurements are overlapped. Between each measurements, the gap is opened to 100mm and closed to the measurement gap.
- 1.5 Gauss difference translates to 1.0 μm gap error.

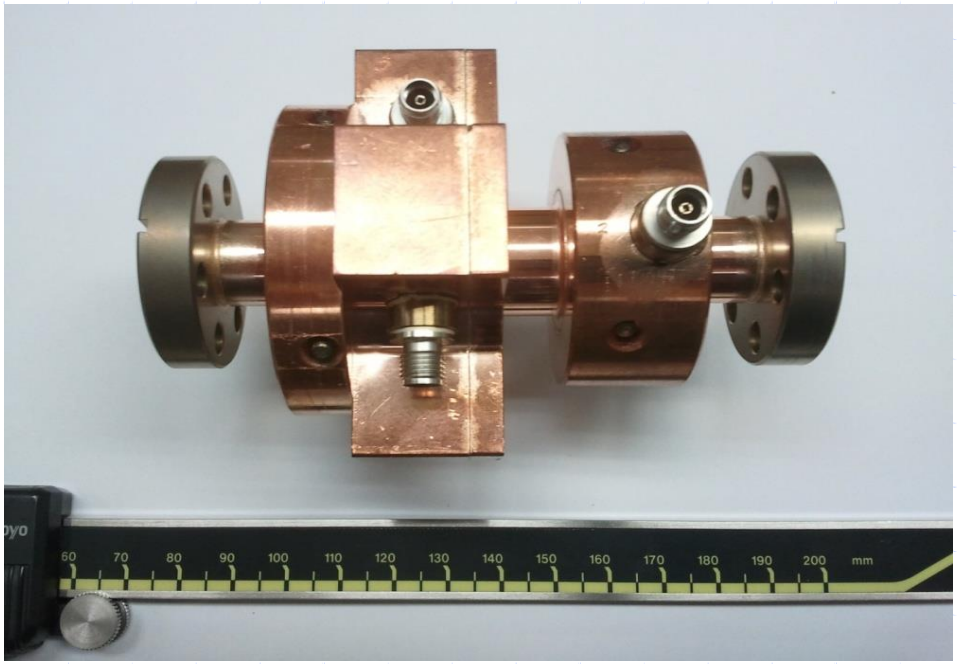
Prototype production of ID chamber

Parameter	Value
Undulator length , m	5.0
Undulator period , cm	2.44
Undulator gap , mm	7.2
Material	A6063-T5/T6
Aperture (V x H) , mm	5.2 x 11
Thickness , mm	0.5±0.05
Flatness	< 50
Clearance (pole to chamber), mm	0.5

Surface measurement result
- Surface roughness : < 150 nm
- Oxidation layer thickness : < 5 nm

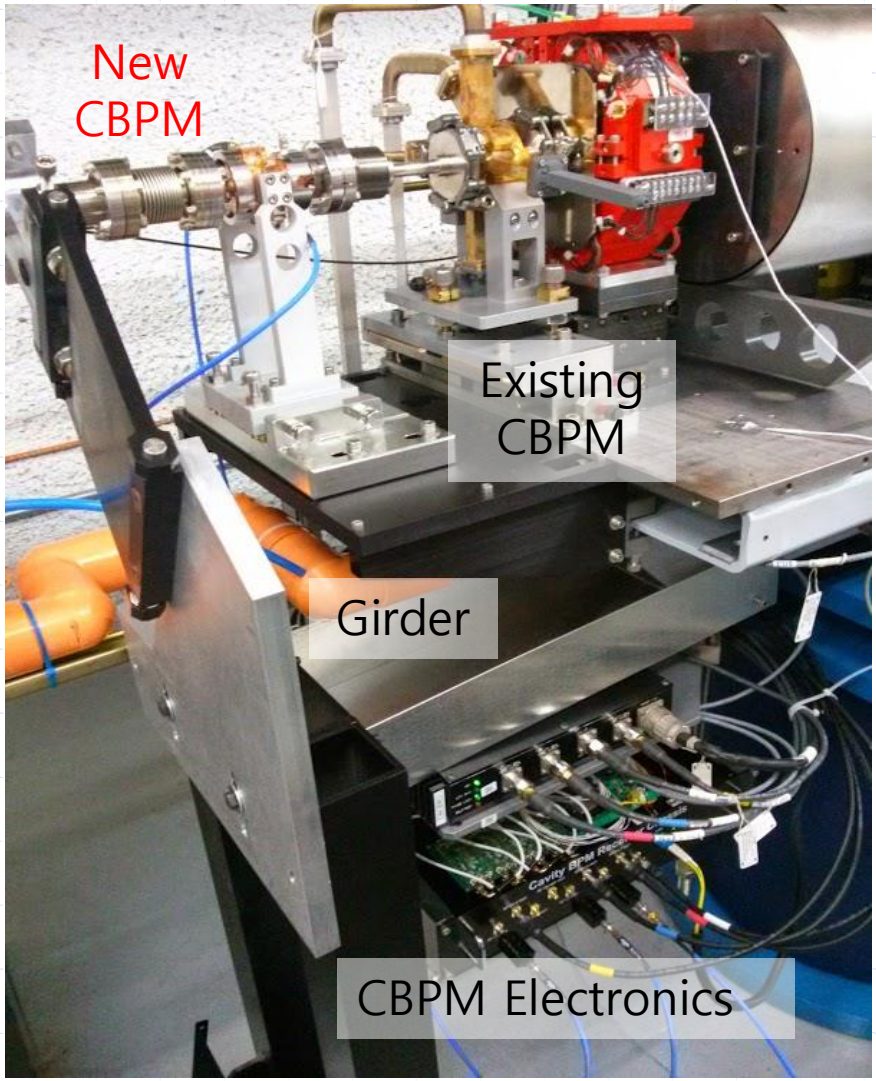
X-band Cavity BPM

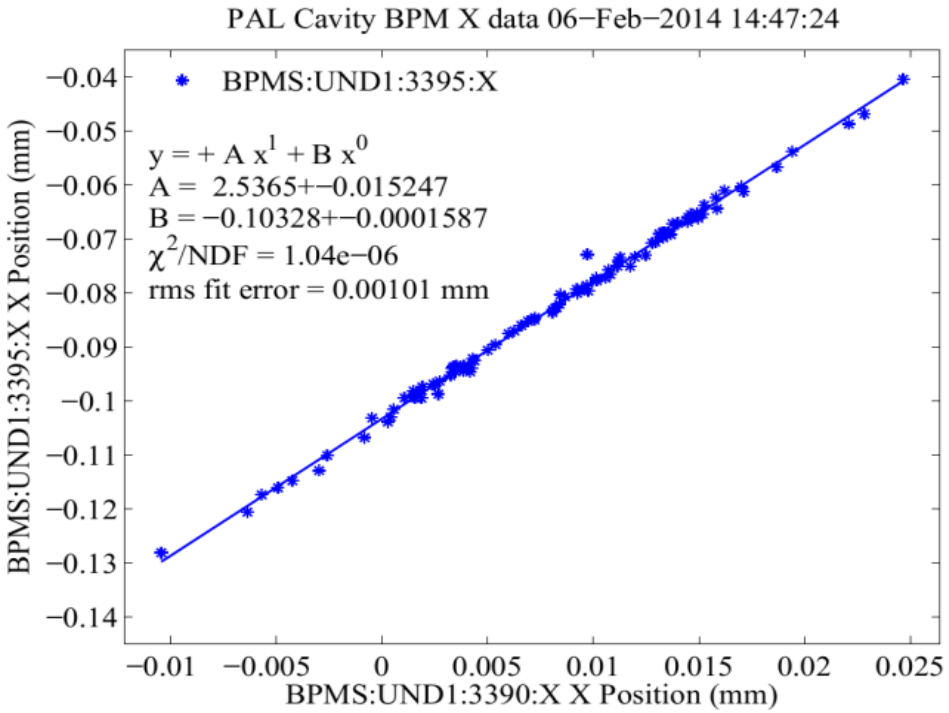




Parameters	XY Cavity (Dipole Cavity)	Reference Cavity (Monopole Cavity)
Mode	TM110	TM010
Frequency	11.424 GHz	11.424 GHz
Loaded Q Factor	2000 – 3000	2000 – 3000
R/Q	> 2 Ohms/mm	> 12 Ohms
Induced Voltage	> 5 mV/pC·mm	> 20 mV/pC
X/Y Cross Talk Level	< -20 dB	-

Beam Test at LCLS





1 micron resolution
measured at LCLS

Summary: What have done

- PAL XFEL Project: 2011-2015 with Total Cost of 400 Billion Won (~400MUSD).
- 39 old PLS and 34 new members are working now.
- Building construction started in September 2012.
  - Removed ~ 1.2 million m^3 of soil, and soft ground replaced with massive concrete.
  - New 154 kV power transmission line is placed by underground pass.
  - Utility works underway.
- Injector Test Facility completed: Beam study underway.
- ID field measurement system ready.
- Major procurements decided in 2013-2014.
  - 120 units of quasi-symmetric ACs ordered to MHI, 57 to domestic company
  - 50 units of 80 MW klystron ordered to Toshiba
  - 50 units of 200 MW modulator ordered to domestic companies.
  - LLRF systems ordered to domestic companies
  - 18 undulators (HX) ordered to domestic company
  - ~700 MPS ordered to domestic company

Summary: What to do

- Machine installation team formed.
- Installation of key components and their conditionings will be carried out by manufacturers.
- Machine installation will be started in September 2014.
  - LCW piping/manifolds almost done
- Entire building and utilities will be ready by the end of 2014.
- Beam commissioning will be started from January 2016.
  - International commissioning team will be formed.
- First pilot experiment will be started in late 2016.

Thank you!