

Construction of 8 GeV C-band Accelerator for XFEL/SPring-8

Takahiro Inagaki
for XFEL project in SPring-8, Japan



Outline

- Introduction**
- Production quality and performance**
- Installation status**

Compact XFEL facility in SPring-8

X-ray FEL

SPring-8
storage ring
8 GeV

Concept

1) In-vacuum undulator

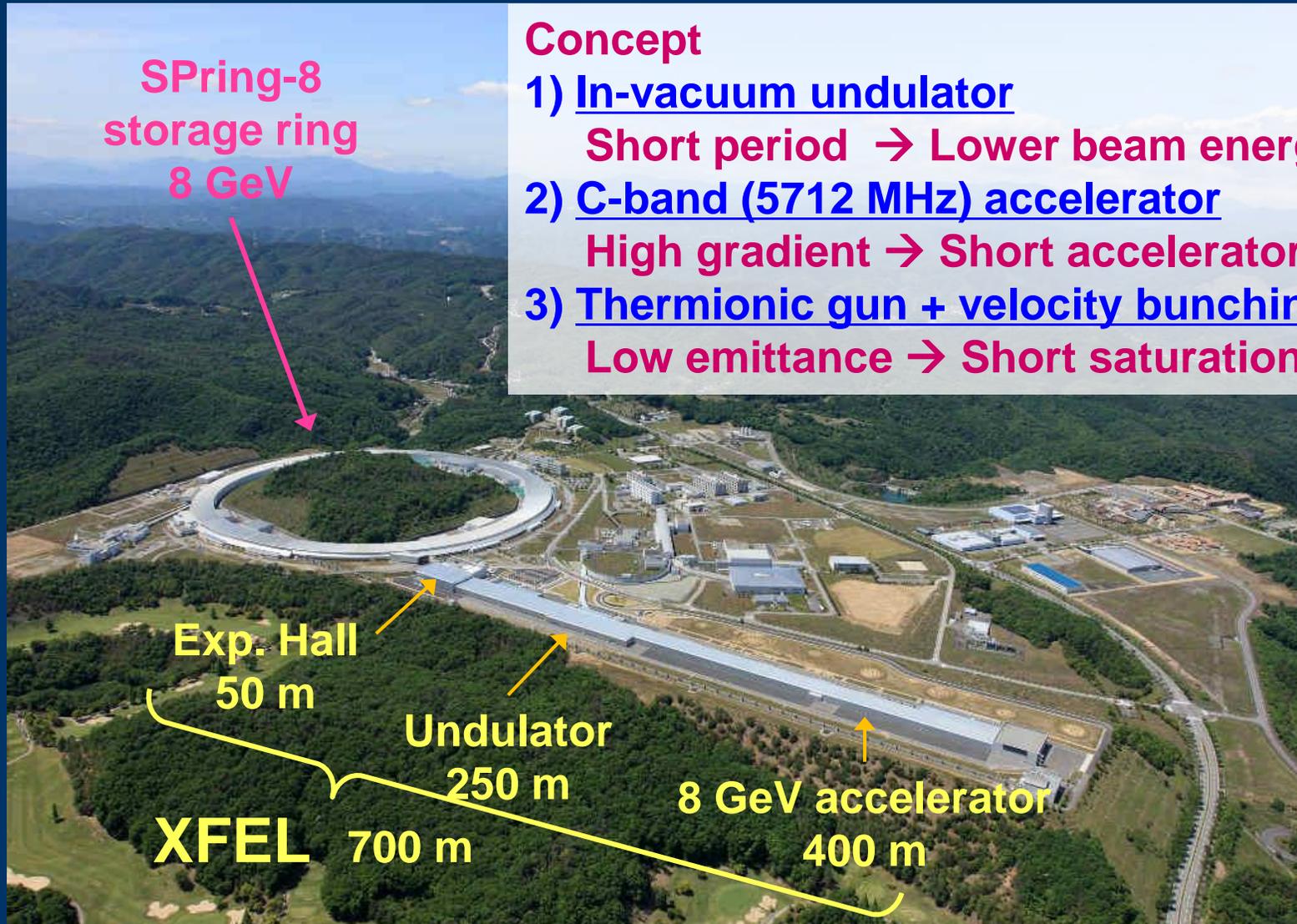
Short period → Lower beam energy

2) C-band (5712 MHz) accelerator

High gradient → Short accelerator length

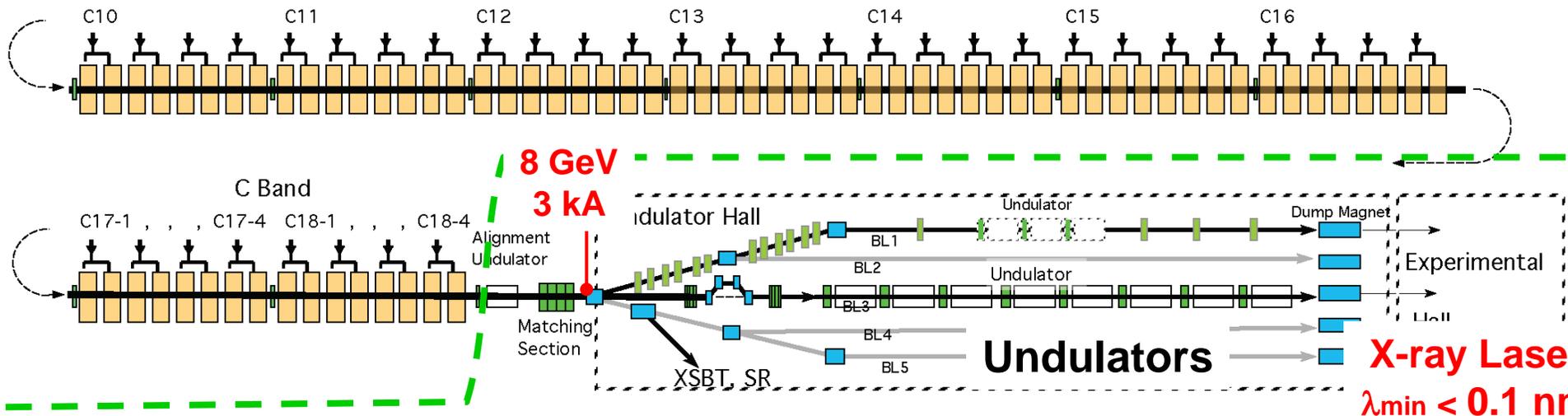
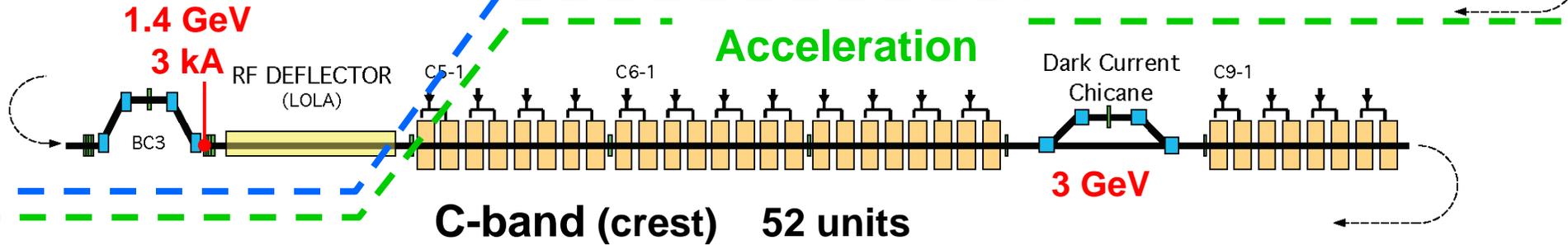
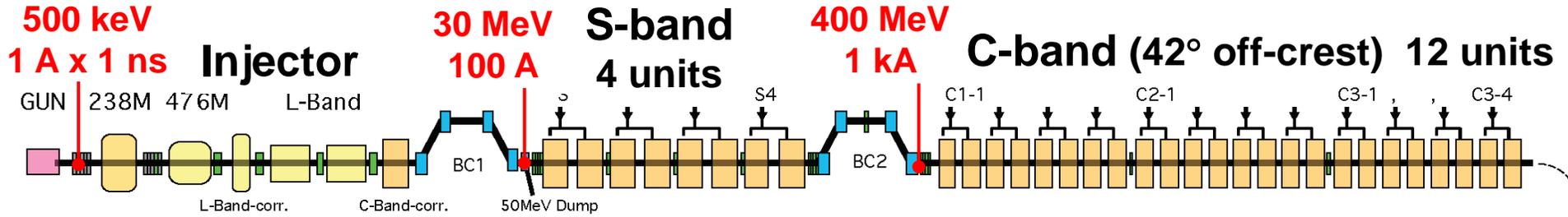
3) Thermionic gun + velocity bunching

Low emittance → Short saturation length



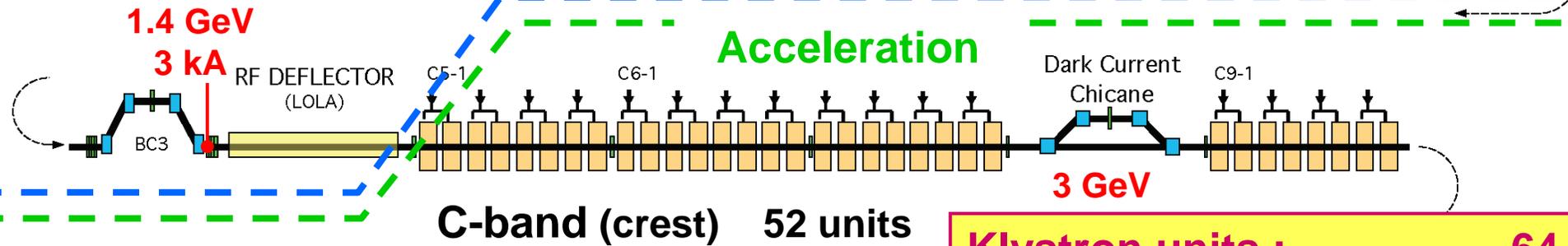
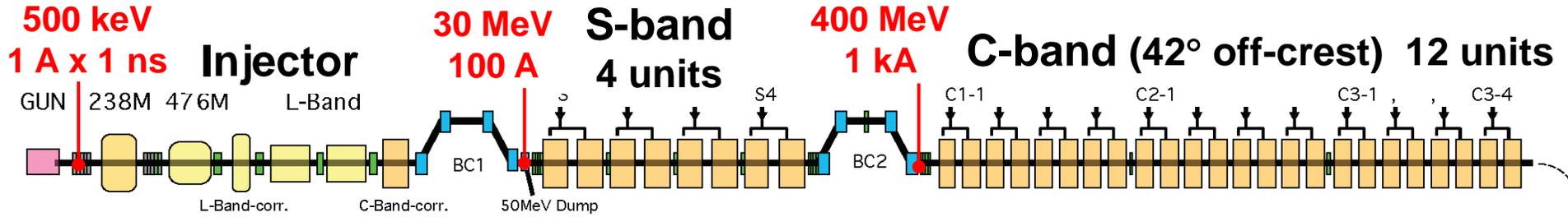
SPring-8 XFEL machine configuration

Bunch compression



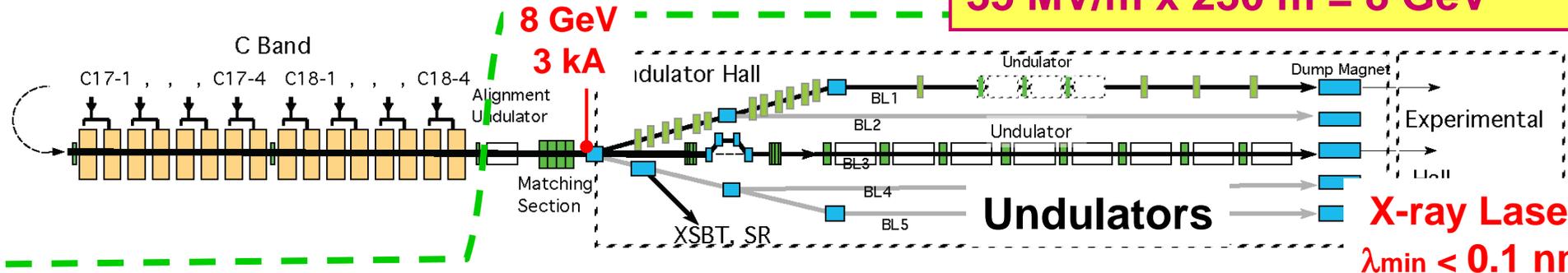
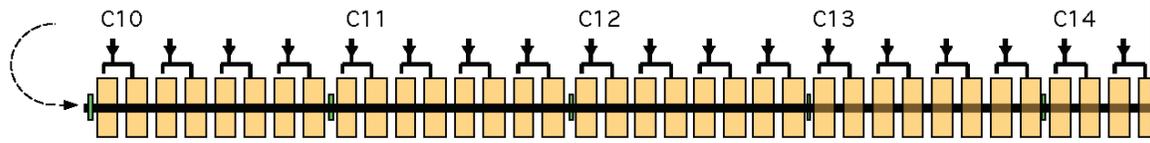
SPRING-8 XFEL machine configuration

Bunch compression



Klystron units : 64
Accelerating structures : 128

35 MV/m x 230 m = 8 GeV



History of C-band

X-ray FEL

1996 ~ 2002 500 GeV Linear collider

H. Matsumoto & T. Shintake @ KEK developed C-band components

- Klystron
- Accelerating structure
- Waveguide components
- Cavity-BPM
- ...



2005 ~ SCSS test accelerator (EUV-FEL)

Practical use of C-band

- High acceleration gradient (37 MV/m)

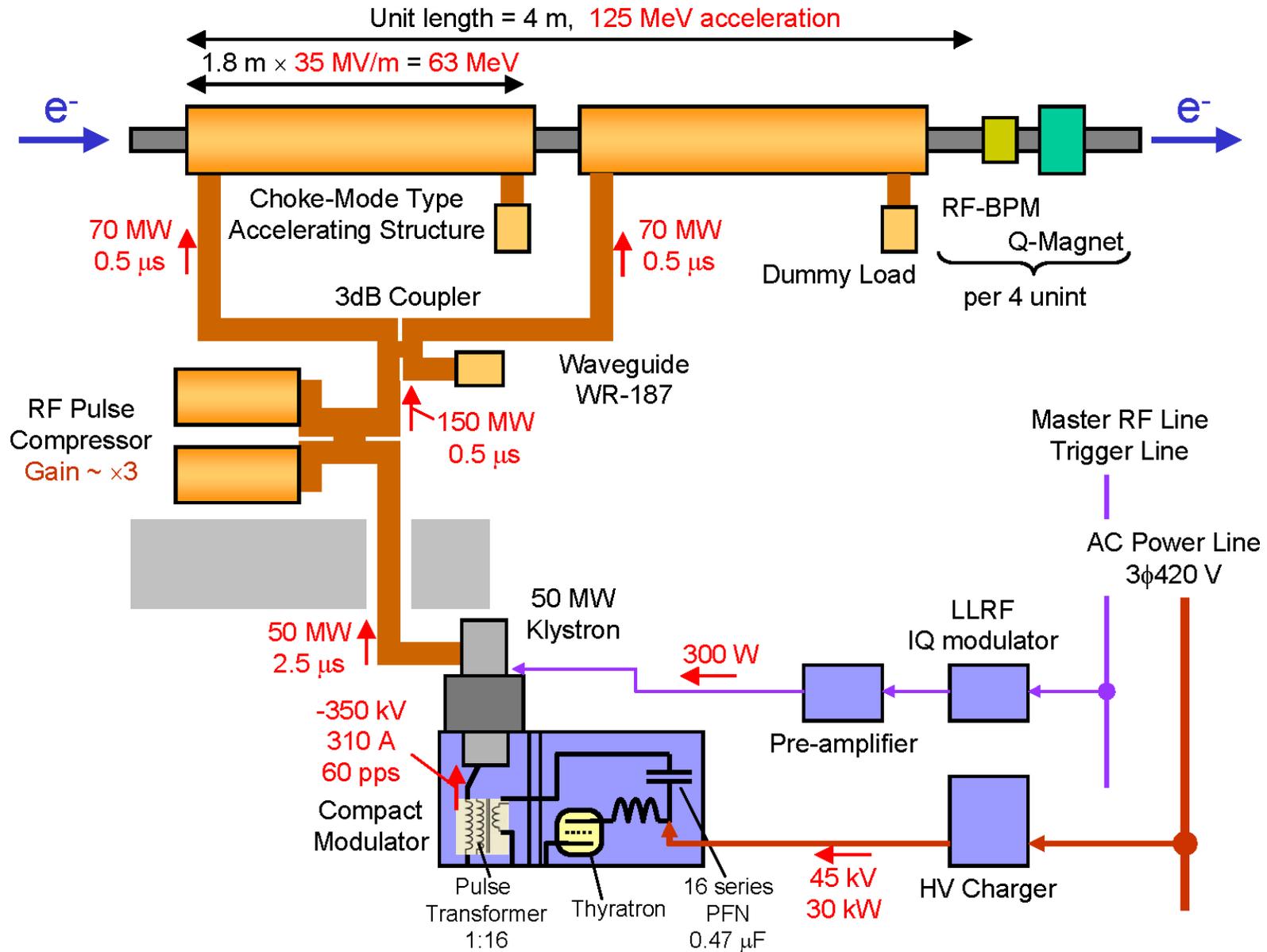


2007 ~ XFEL construction

- 2007 ~ Mass production
- 2009 ~ Installation

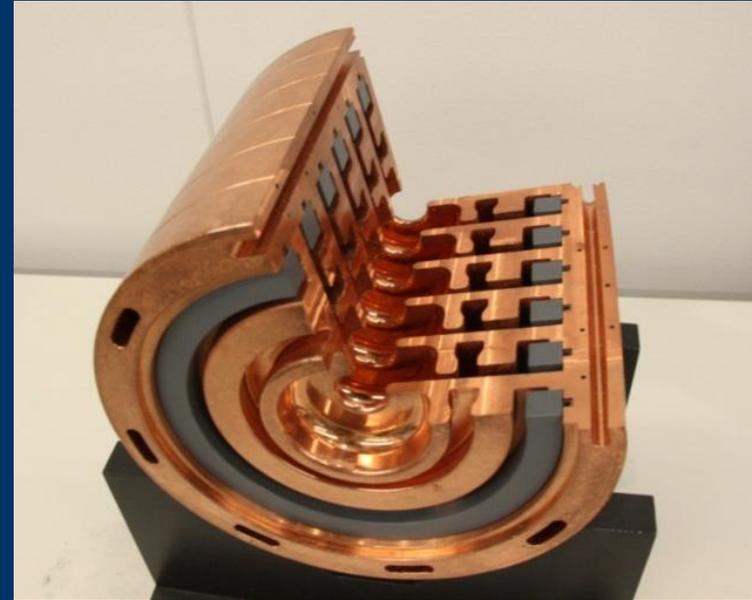
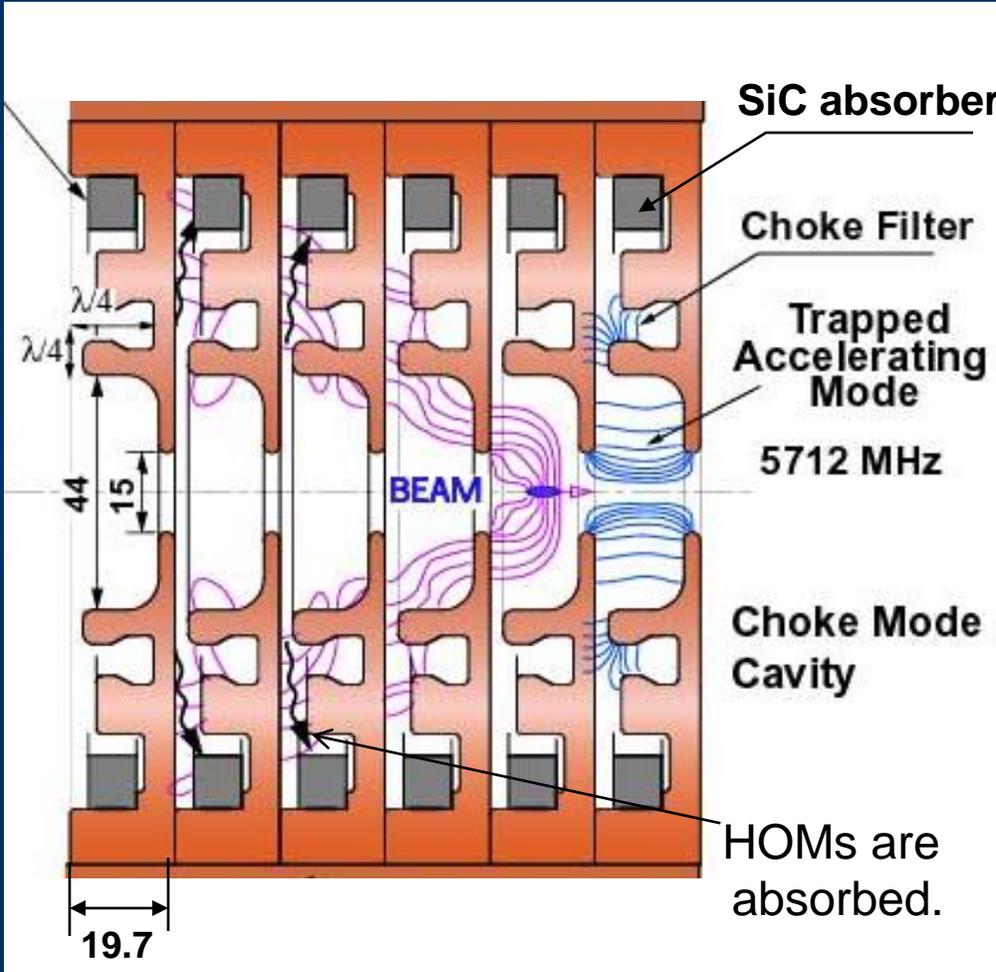


C-band (5712 MHz) RF system



Accelerating structure

X-ray FEL



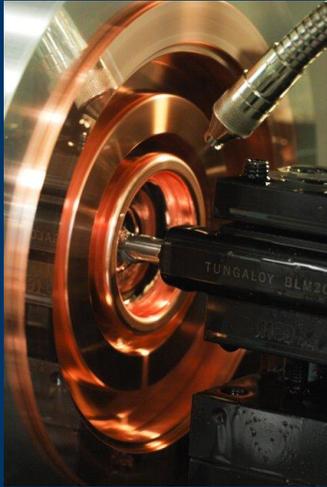
Accelerator type	Traveling wave Constant gradient
Number of cell	89 +2 coupler cells
Length	1.8 m

Choke mode cavity (Shintake 1992)
HOM damping for multi-bunch operation

Fabrication of the accelerating structure

by Mitsubishi Heavy Industries Ltd.

X-ray FEL



Precision machining



Vertically stacked



Brazing

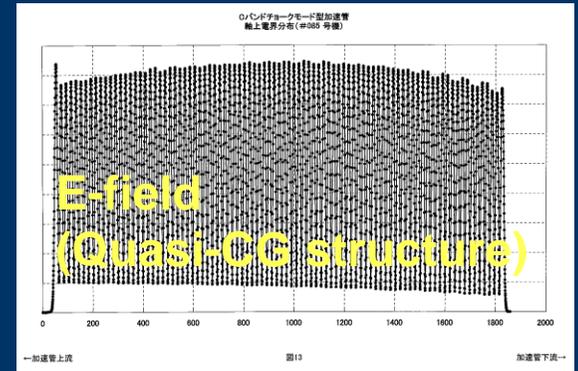


Final inspection

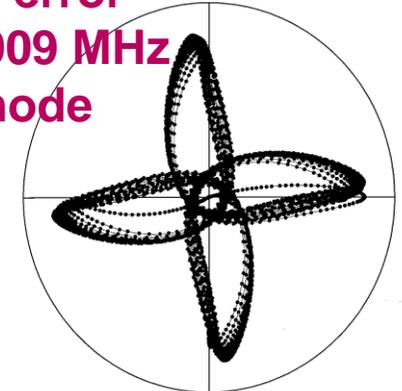


We cannot tune the cavity by the dimpling method.

Bead measurement (Typical result)

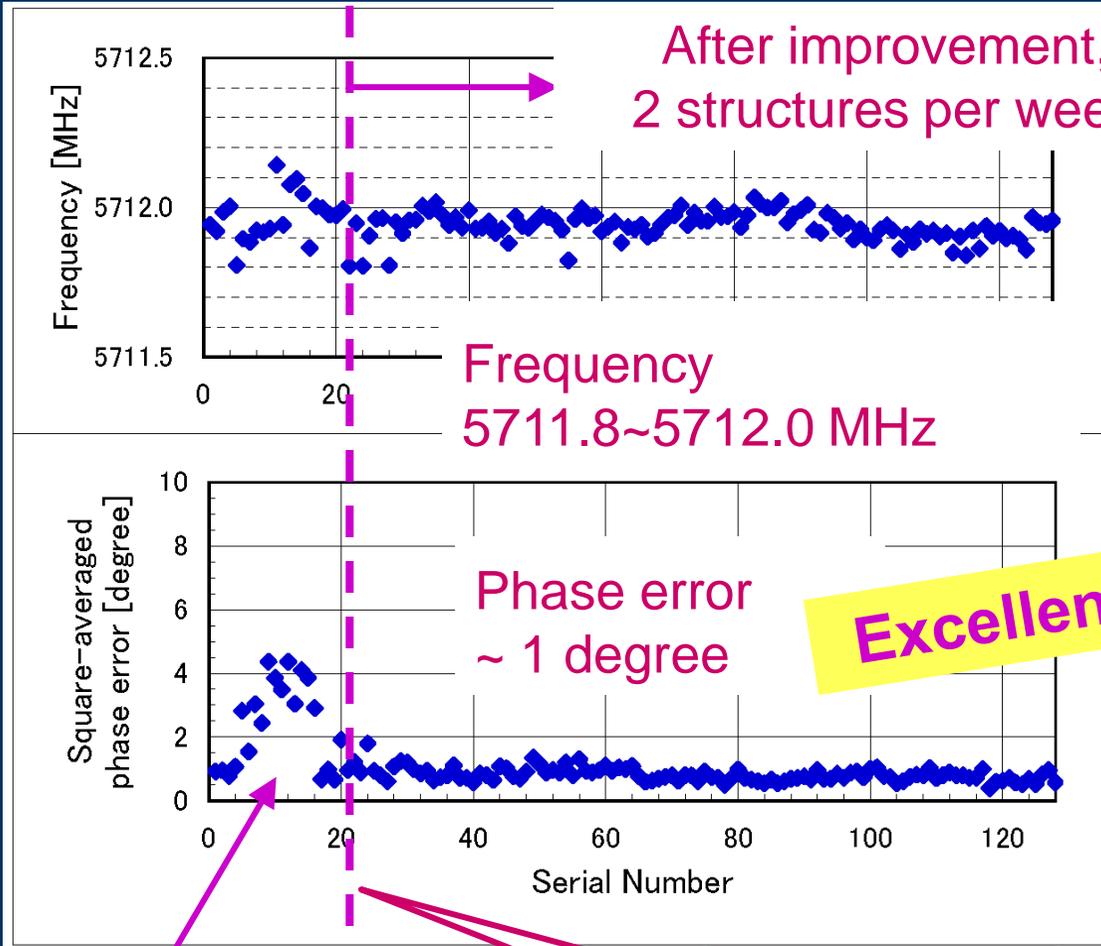


Phase error
5712.009 MHz
 $3\pi/4$ mode



Production of 128 structures (2007 ~ 2009)

X-ray FEL

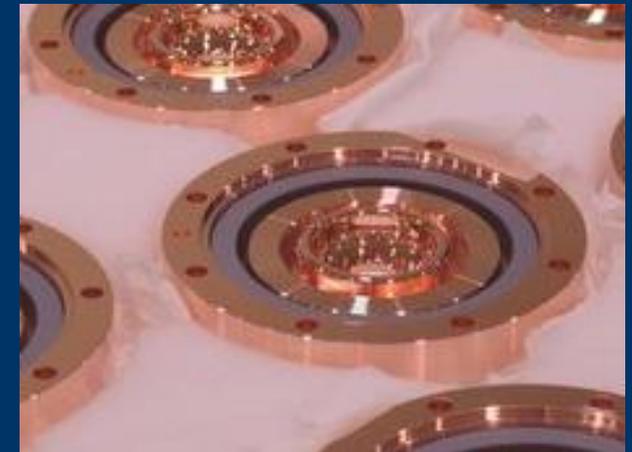


Precisely machined but brazing was unstable

Stopped 4 months



Sadao Miura
(Mitsubishi Heavy Industries)

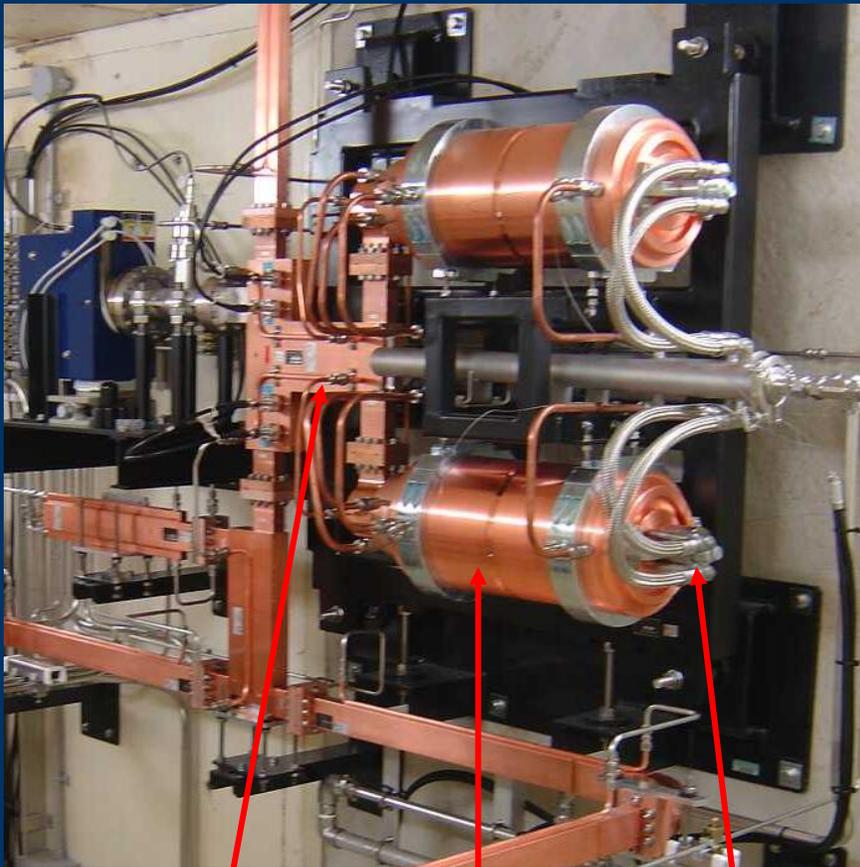


Finally he found SiC ring distorts the cavity during the brazing process.

Mass production of 64 pulse compressors

by Mitsubishi Heavy Industries Ltd.

X-ray FEL

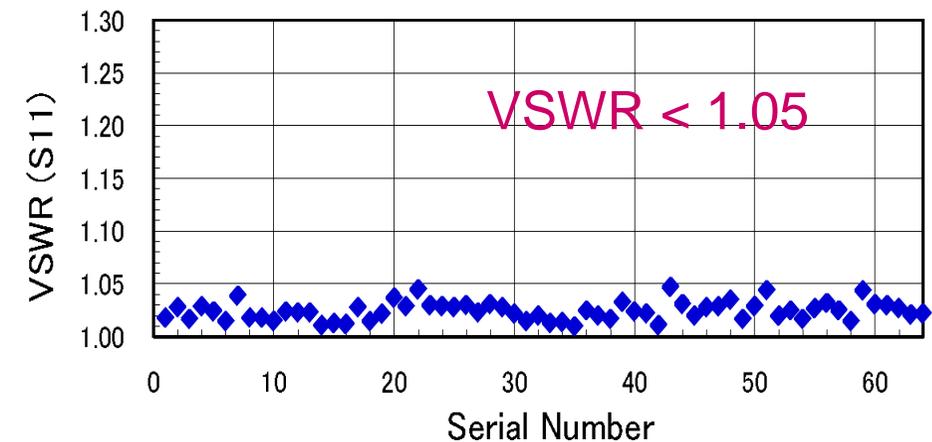
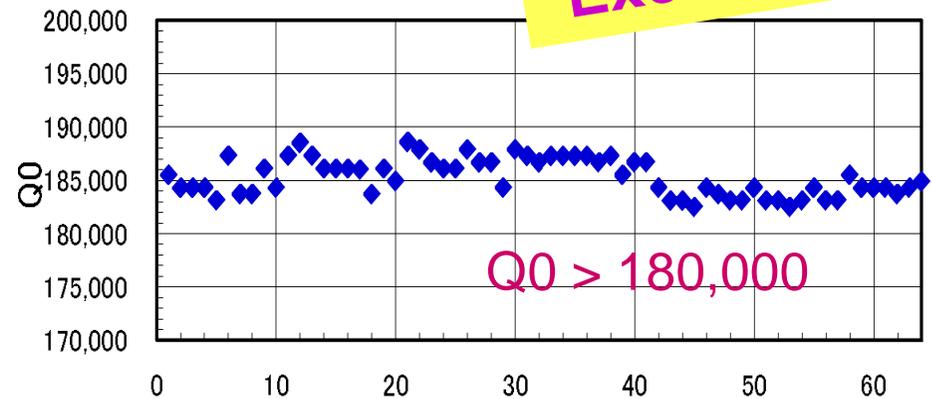


High-Q cavities

Directional coupler

Tuners

Excellent!

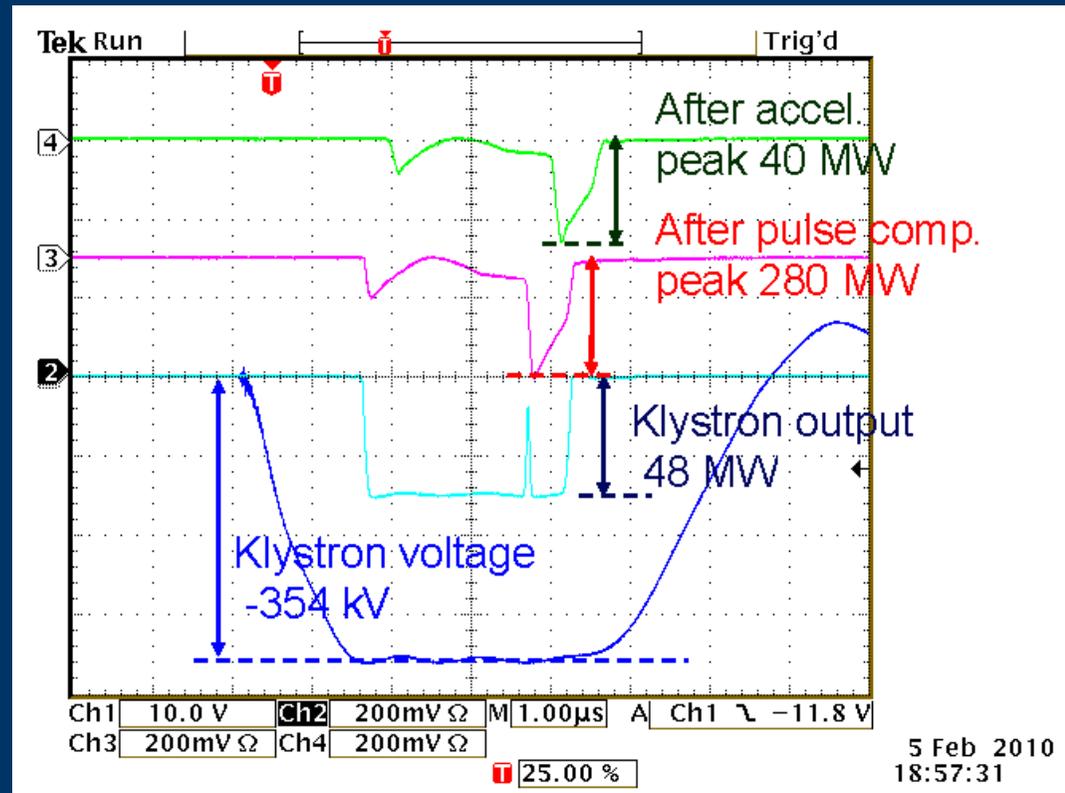


High power RF test (2008 ~ 2009)

X-ray FEL

- We tested 3 different samples from the mass-production.
- Processing up to 40 MV/m, 60 pps.
- Stable operation at nominal 35 MV/m, almost no RF trip (discharge)

Typical waveform ($E_a \sim 40$ MV/m)



Installation (Aug. 2009 ~ May 2010)

X-ray FEL



Waveguide connection

Laser tracker

Alignment accuracy
~ 0.1 mm

Ready to run

X-ray FEL



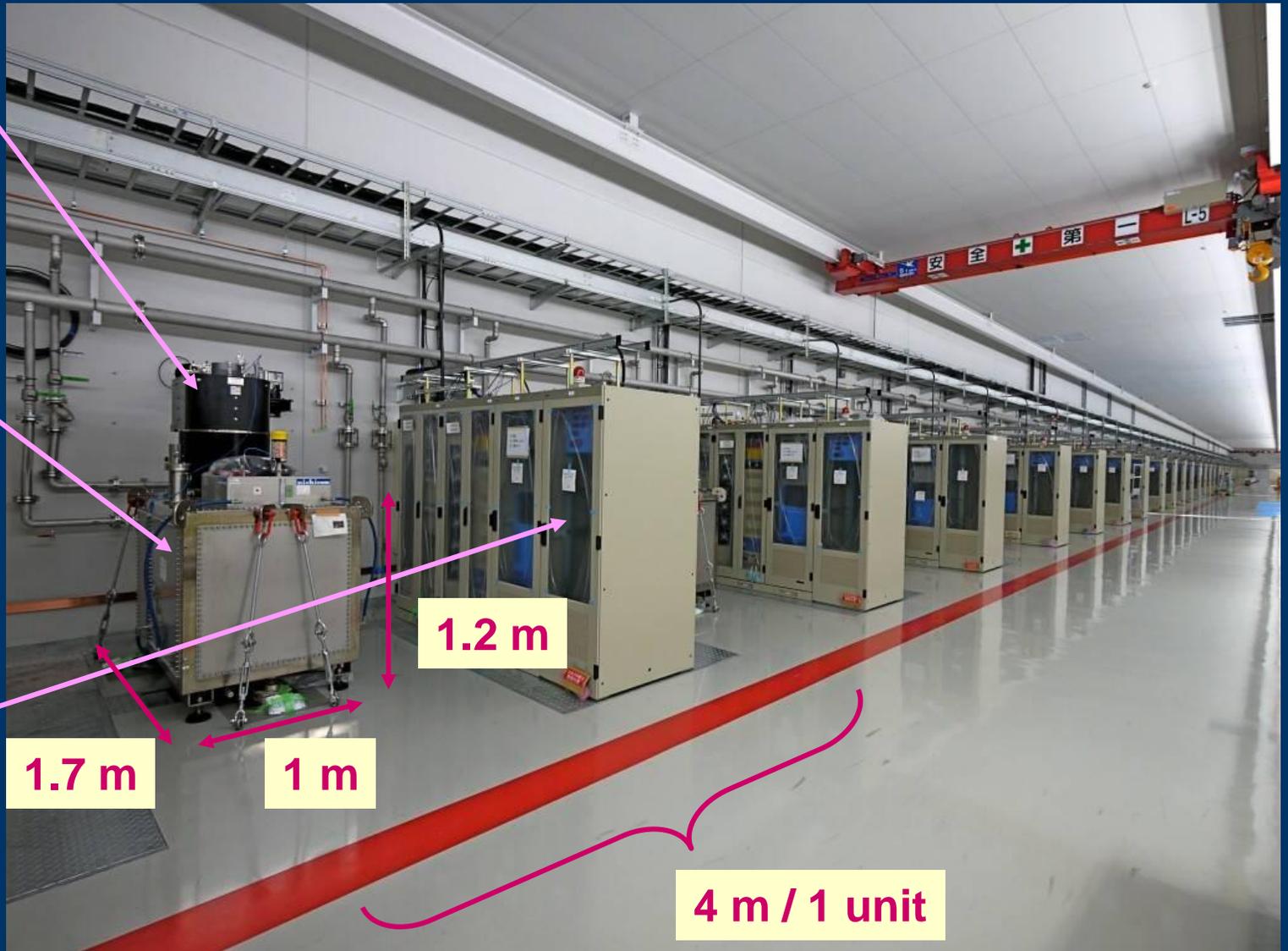
For the high gradient accelerator, we need a compact klystron modulator

X-ray FEL

Klystron
50 MW

Modulator
350 kV
110 MW

**Inverter-type
HV charger**
50 kV
35 kW
Stability ~
10 ppm (STD)



For the high gradient accelerator, we need a compact klystron modulator

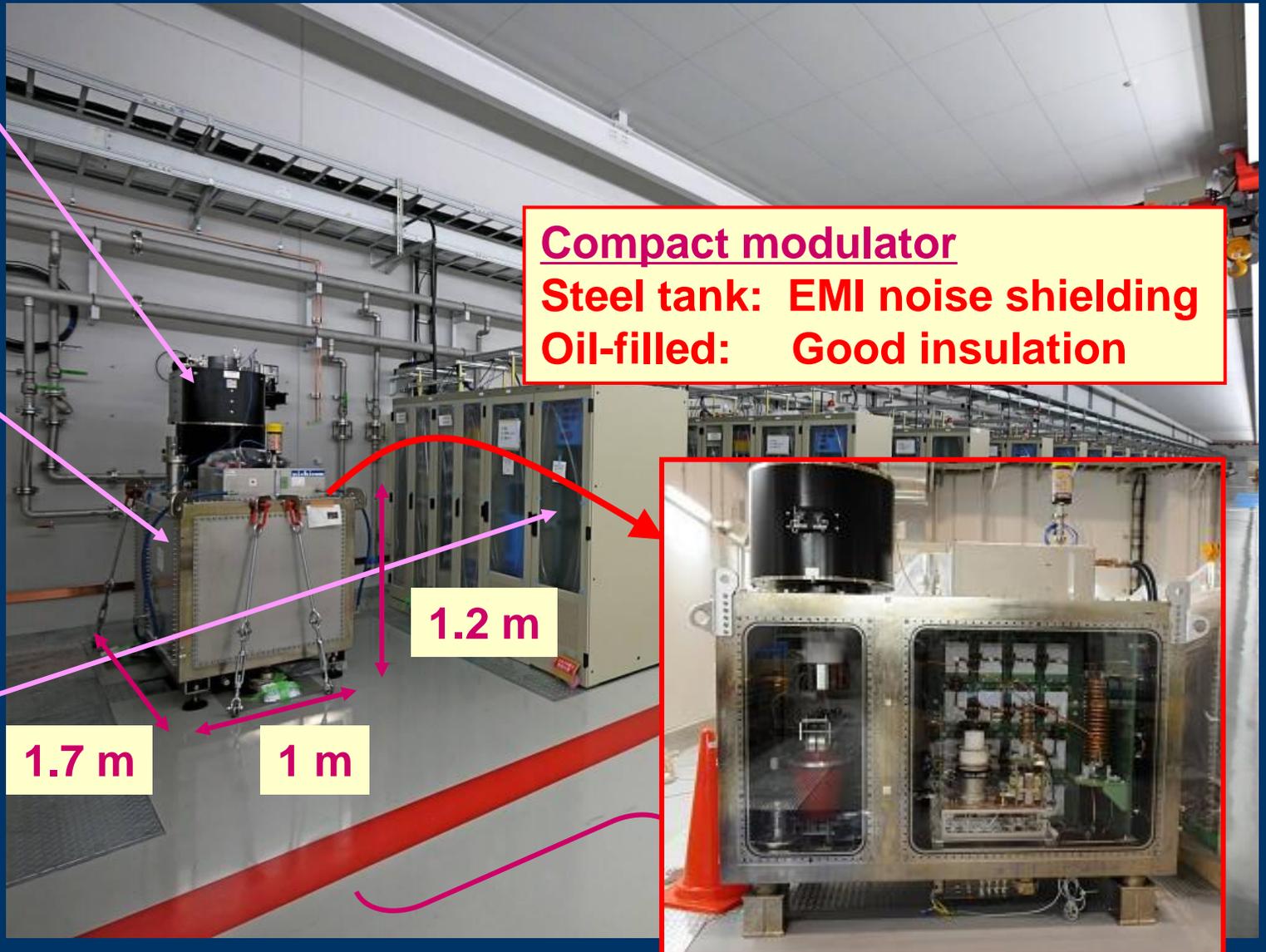
X-ray FEL

Klystron
50 MW

Modulator
350 kV
110 MW

Inverter-type
HV charger
50 kV
35 kW
Stability ~
10 ppm (STD)

Compact modulator
Steel tank: EMI noise shielding
Oil-filled: Good insulation



Mass production of modulators (2008 ~ 2010)

X-ray FEL

by Nichicon Corp.



In the factory
- Assembly
- High voltage test

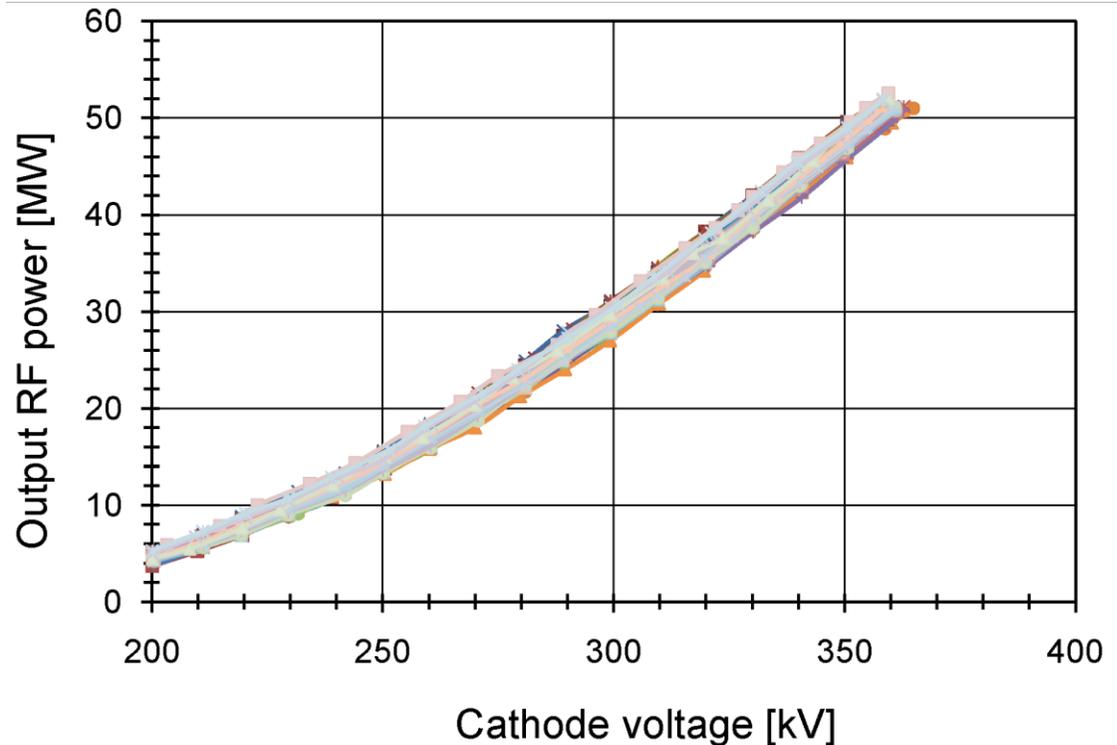
Mass production of klystrons (2007 ~ 2010)

X-ray FEL

TOSHIBA TETD Co.ltd.
Model: E37202



Factory test
Overlaid of 60 klystrons



Installation (July 2009 ~ May 2010)

X-ray FEL



Assembly hall



8 hour operation test



Klystron assembly



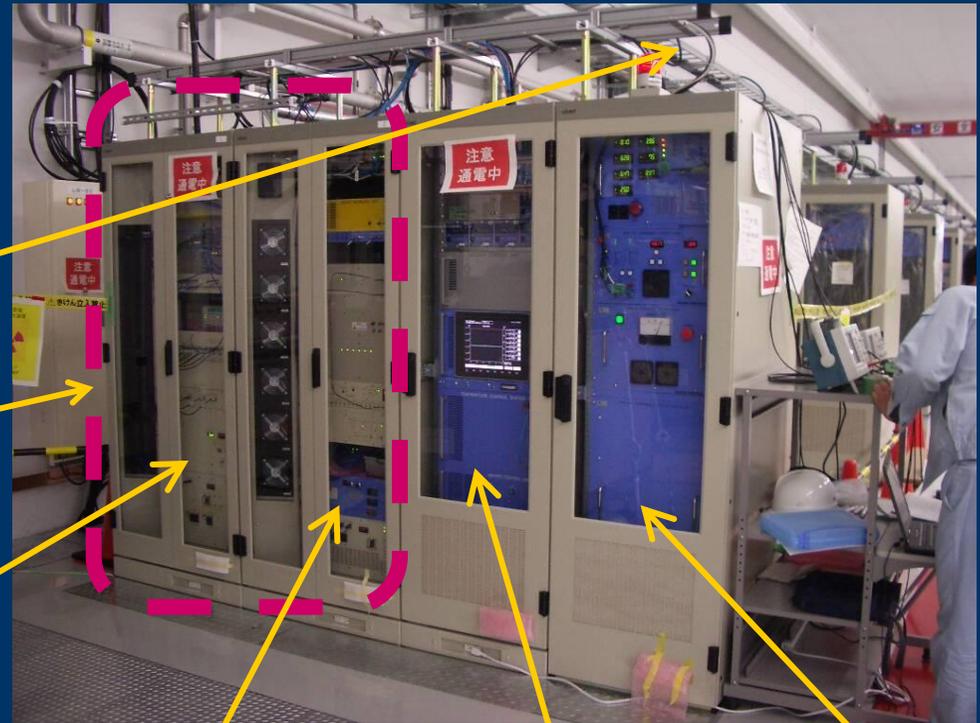
Delivered to the klystron gallery

Timing and LLRF in the cabinets

Timing and LLRF team (Y. Otake, T. Ohshima, ...)

X-ray FEL

Temperature stabilization for ultra stable timing and RF system.



Water cooled duct for optical fiber

Water cooled cabinet

Water cooled components

Rack-A
Timing
LLRF
VME control
Driver amplifier

Rack-B
Beam monitors
Kly. Focus coil

Rack-C
PLC control
Vacuum
Water

Rack-D
HV charger

Summary and schedule

X-ray FEL

- XFEL uses 64 units of C-band (5712 MHz) high gradient accelerator.
- 2007 ~ 2010 Mass production completed with excellent quality.
- 2009 ~ 2010 Most of the components have been installed.
- Oct. 2010 ~ Start high power rf commissioning.
- Early 2011 ~ Start beam commissioning.

