Status of SCSS & X-ray FEL Project in Japan

Presented by T. Shintake, RIKEN/SPring-8

Representing JASRI+RIKEN Joint Team

- **Status of 8 GeV XFEL/SPring-8 Construction**
- **What we learned from SCSS Test Accelerator**

JASRI+RIKEN Joint Construction Team (88)

浅野芳裕　安積隆夫　石井美保　石川哲也　板倉早苗　稲垣隆宏　井上忍　今井智宏　大島隆　大島和雄　大竹雄次　大塚孝　大端通　大畑拓雄　大矢昇治　木田光春　北村全伸　北村英男　木村洋昭　熊谷教孝　原徹　香村芳樹　近藤力　櫻井辰幸　佐野睦　糸賀俊郎　白澤克年　新竹積　壽榮松宏仁　鈴木伸介

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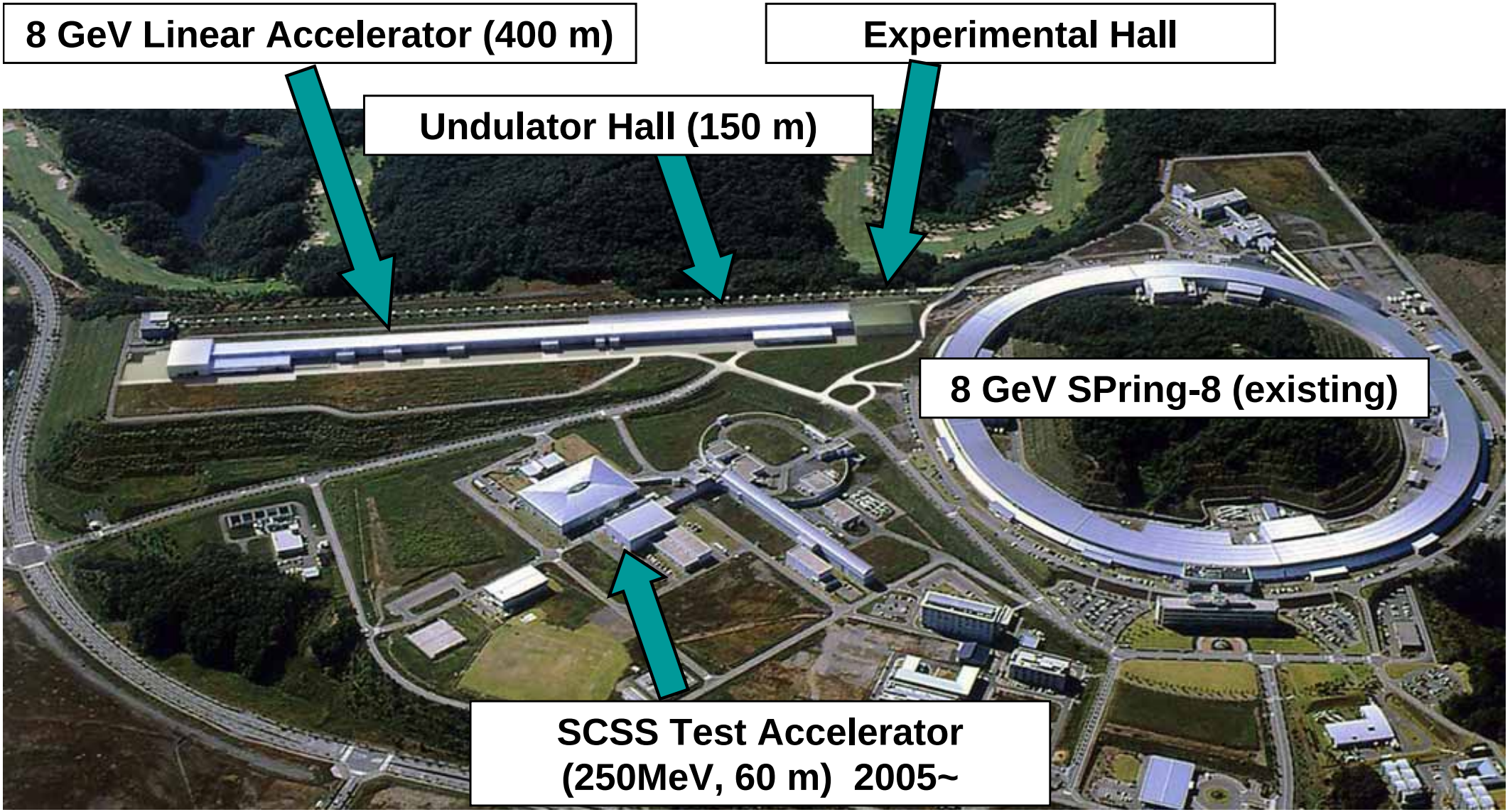
XFEL/SPring-8 Project (CG)



SCSS & X-ray FEL Beam Parameter

at undulator section

		Prototype	X-ray FEL	
Beam Energy	E	0.25	8.0	GeV
X-ray Wavelength	λ	60	0.1	nm
Beam Emittance	ε_n	2	1.0	πmm.mrad
Bunch Length	Δz FWMH	100 0.3	100 0.3	μm psec
Transverse Beam Size	$\sigma_{x,y}$	100	25	μm
Peak Current	I_p	1	3	kA
Charge per bunch	q	0.3	1	nC
Undulator Parameter	λu	15	18	mm
	K	1.3	1.3	
Length	L	10	80	m
FEL Saturation Length	L_{sat}	20	60	m

Tunnel Construction started June 2007

- Accelerator tunnel, on surface.
- Site length 700 m

Construction site (looking down east)

Piling started in June 2007

Stake hole machine’s head.
1.6 m diameter

Vertical drilling machine.

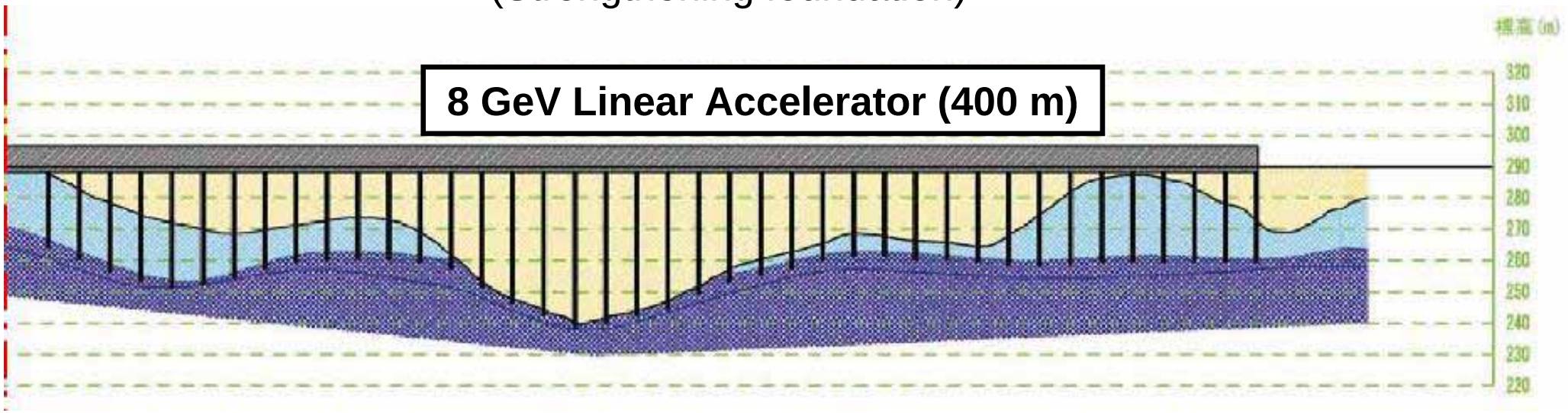
Lifting soil through drilling shaft.

Inserting reinforcing structure.

Filling concrete

Basement Construction

(Strengthening foundation)



：Soil

Soft hardness rock

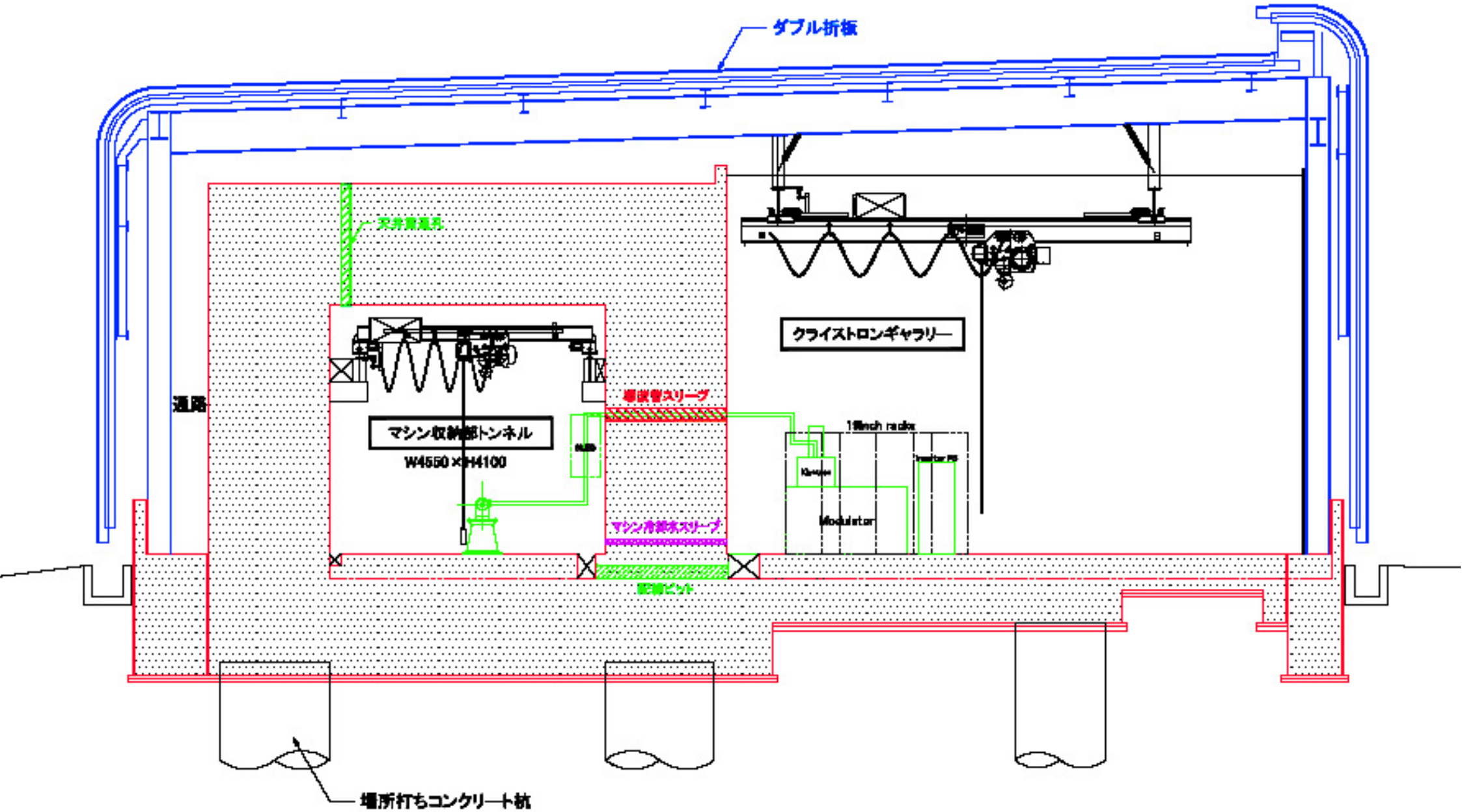
Mid hardness rock

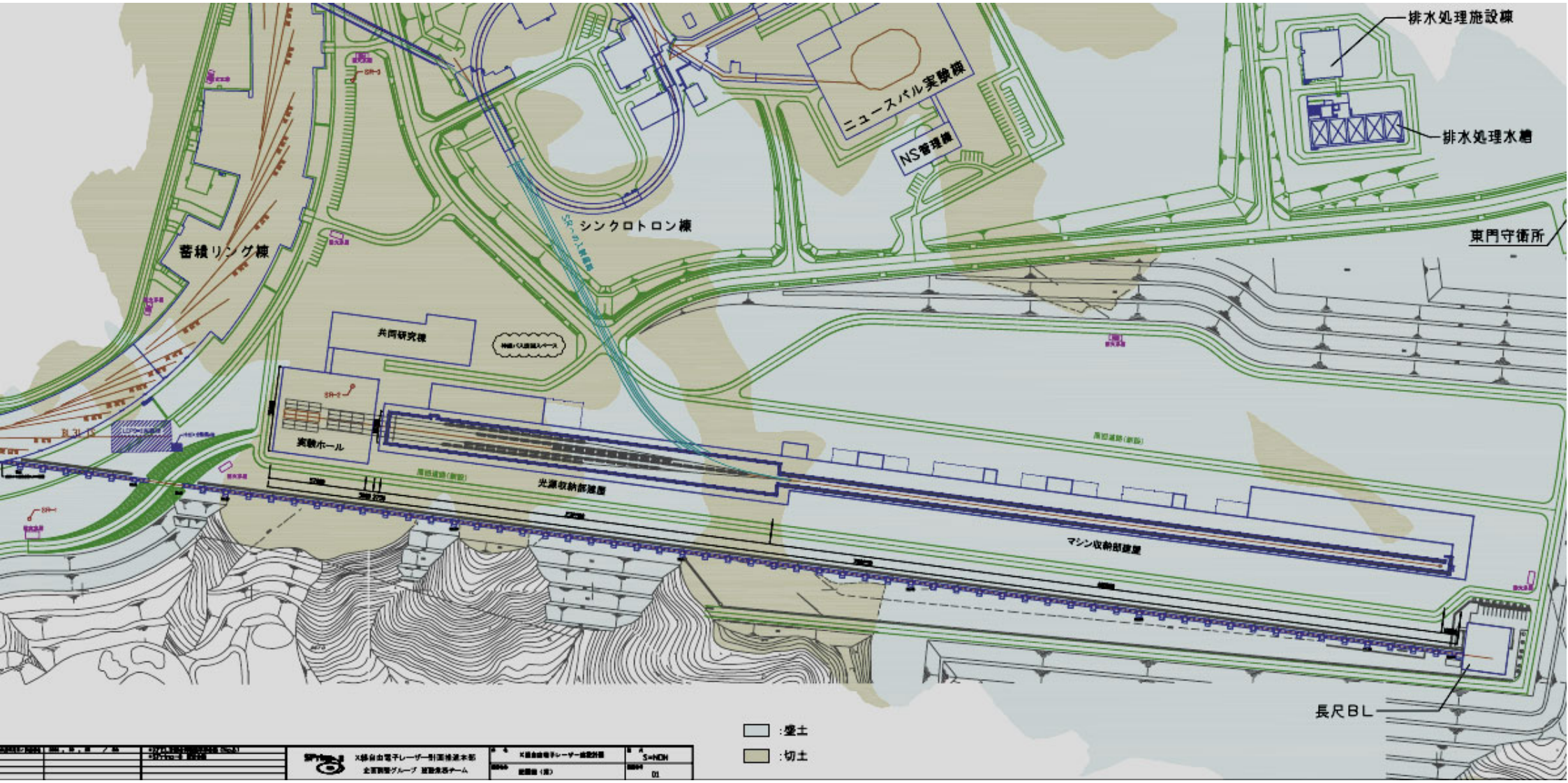
Total Number of stakes: 139

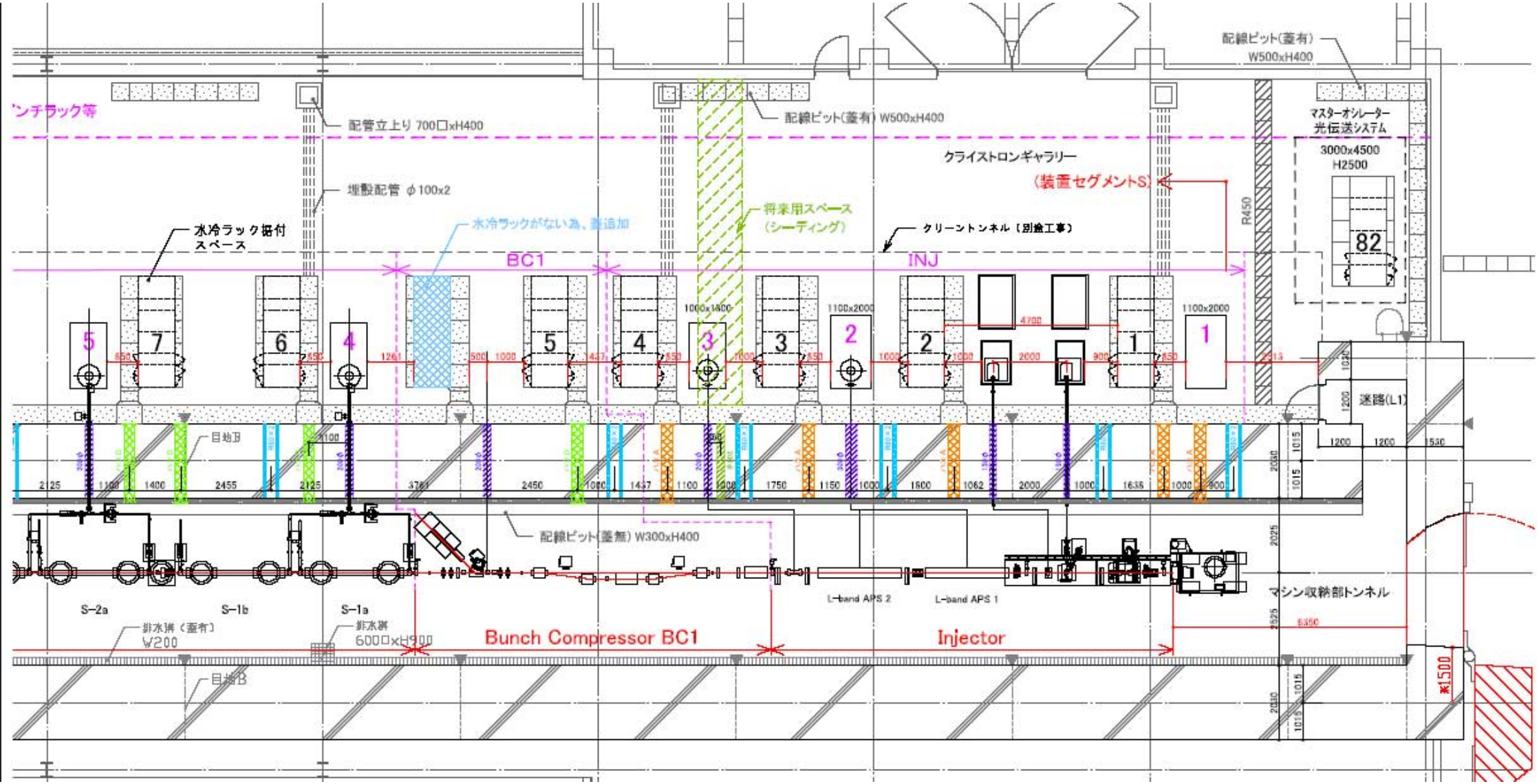
Size : 1.5 m ~ 1.6 m

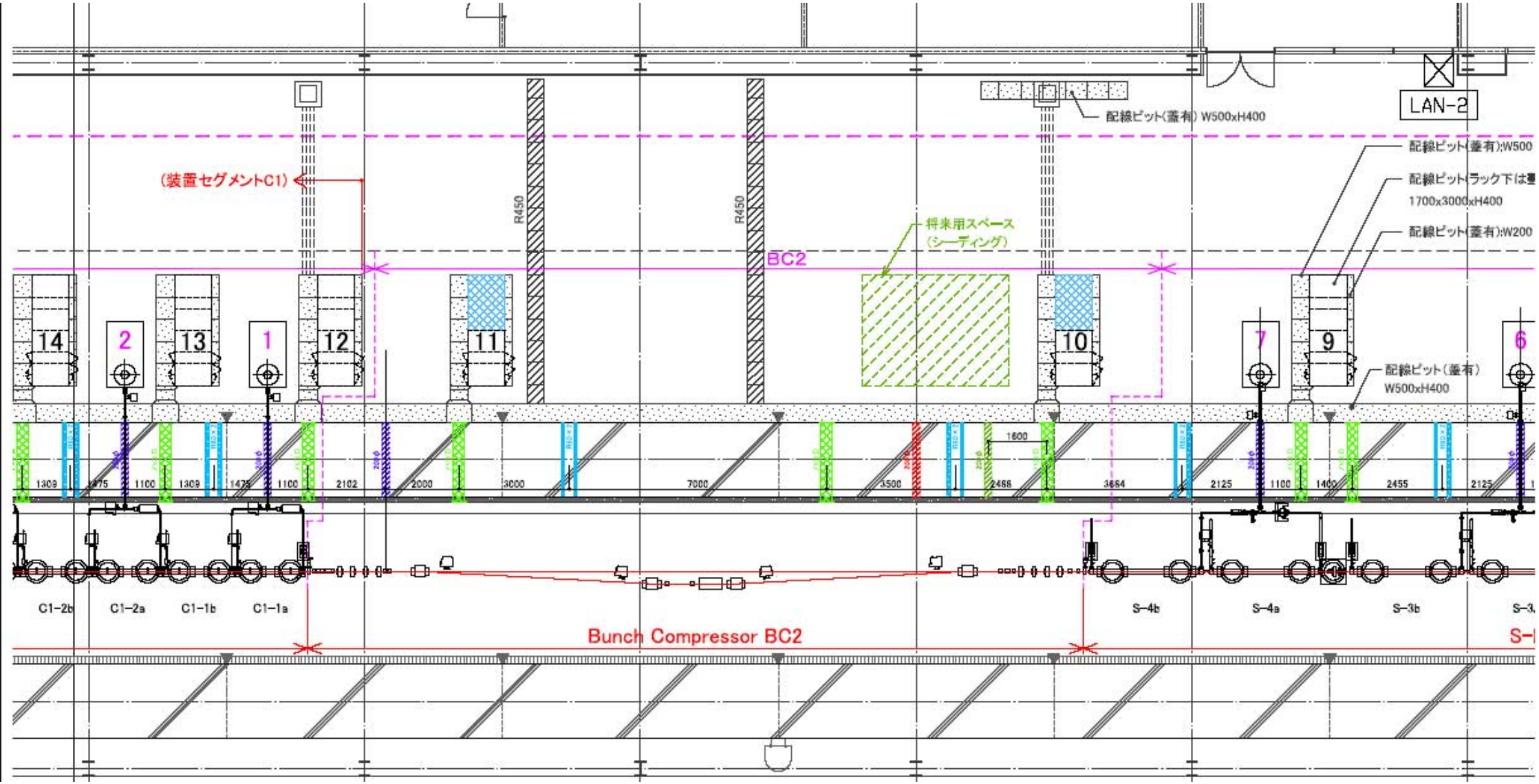
Length: average ~30 m (max 52 m)

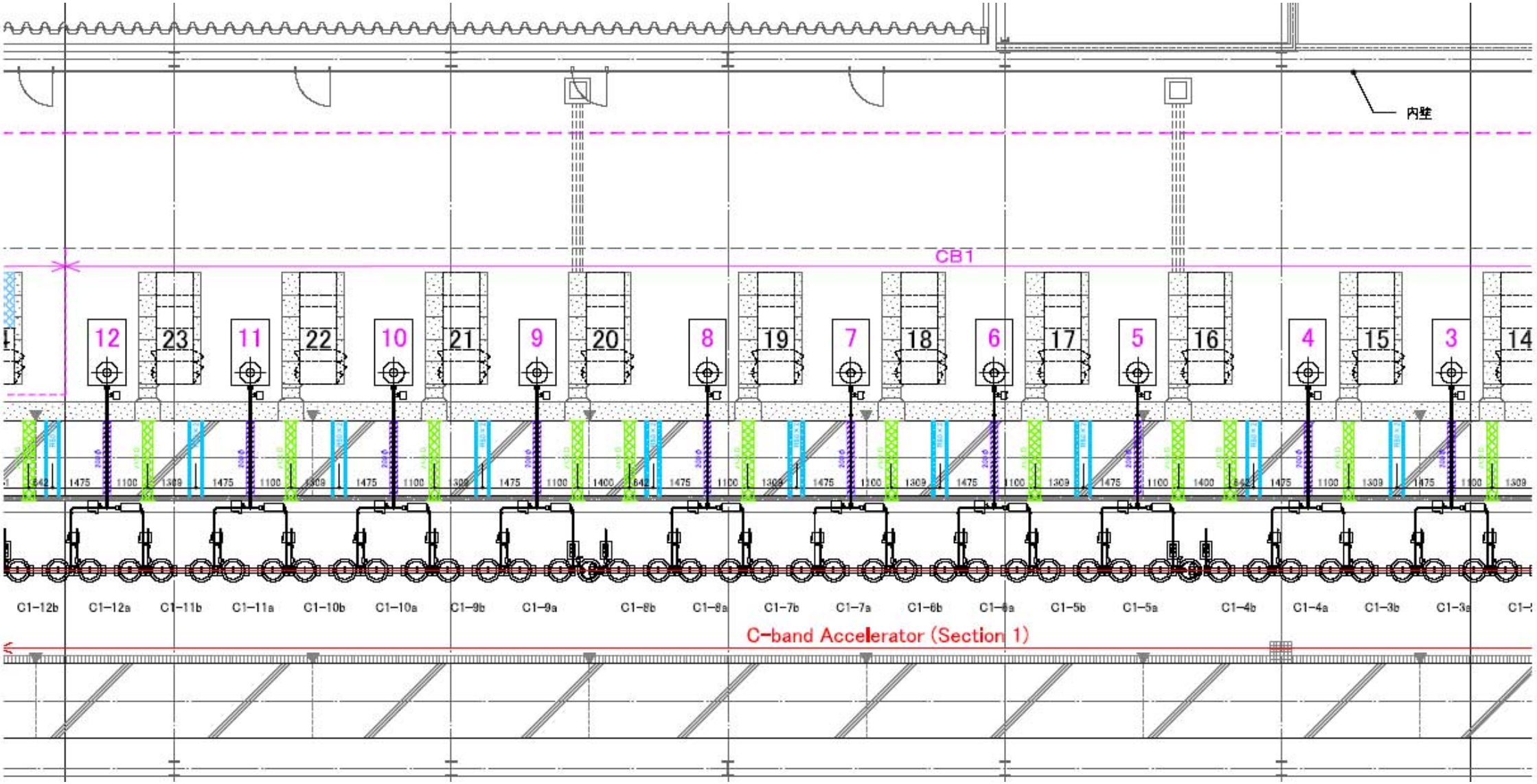
Piling : June ~ October

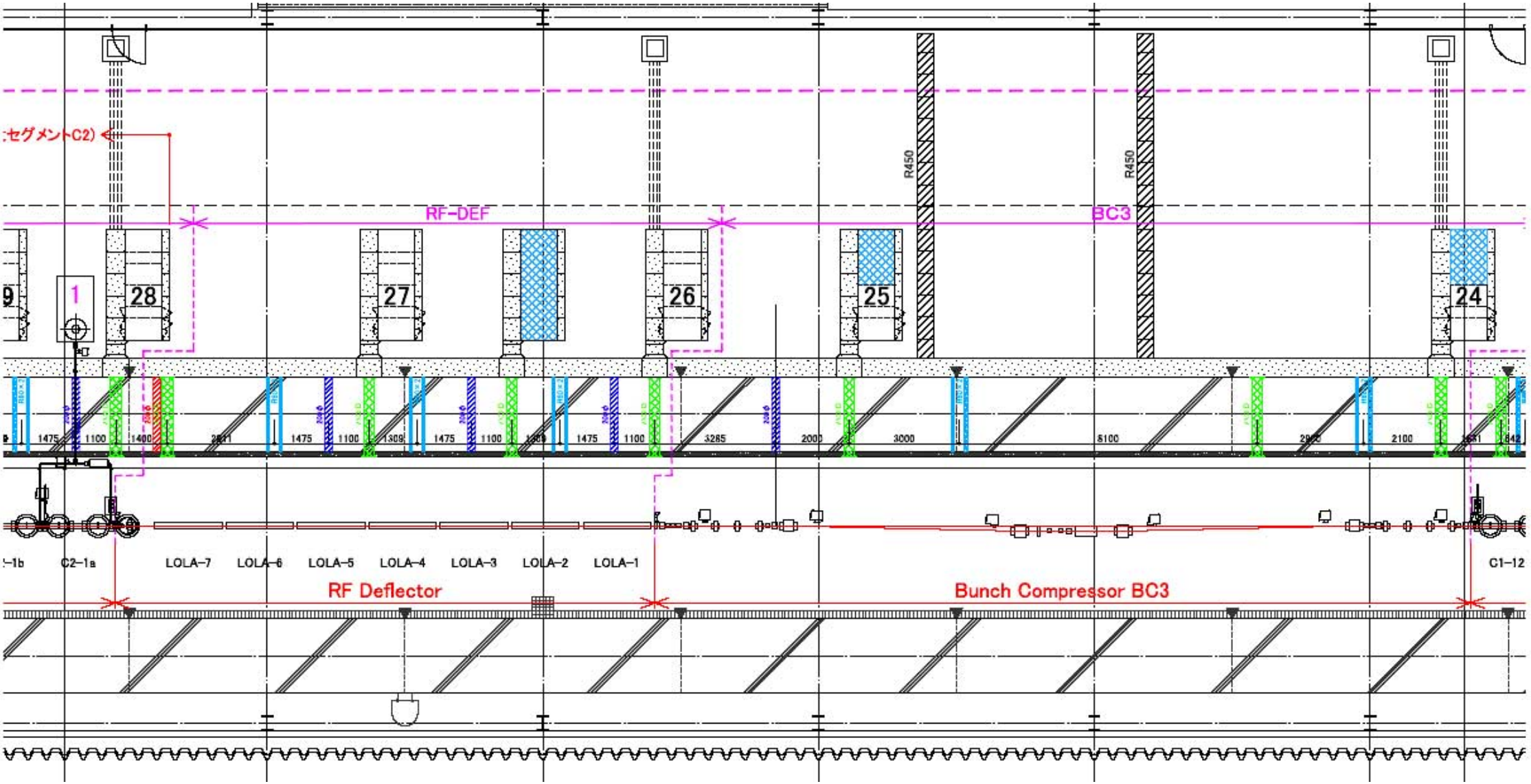

ダブル折板
天井走行クレーン
クライストロンギャラリー
通路
マシン収納部トンネル
W4550×H4100
導波管スリーブ
マシン冷却水スリーブ
1Bench racks
Klystron
Inverter PS
Modulator
場所打ちコンクリート杭

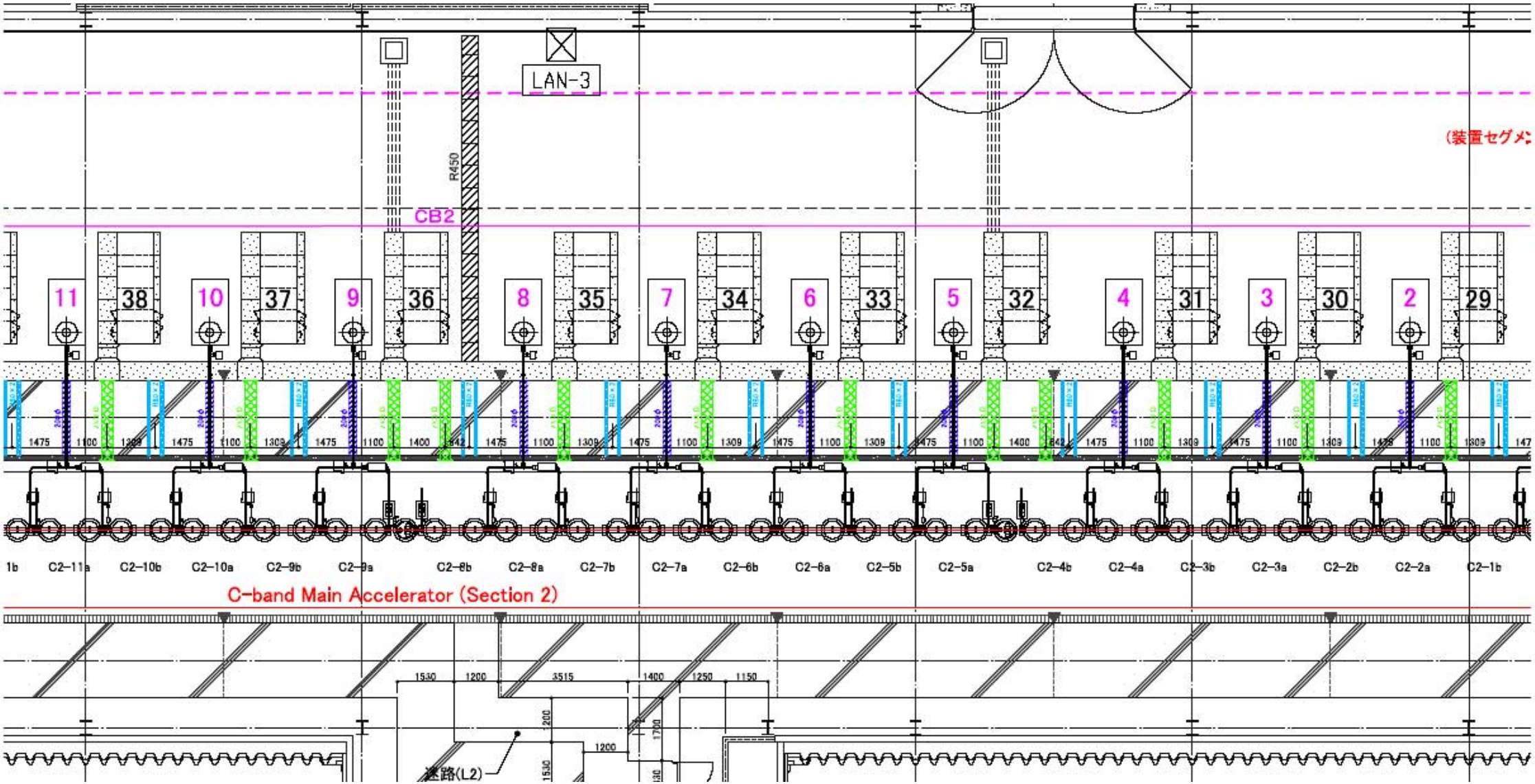

排水処理施設棟
排水処理水槽
ニュースバル実験棟
NS棟
シンクロトロン棟
蓄積リング棟
東門守衛所
共同研究棟
実験ホール
光源収納部建屋
マシン収納部建屋
長尺BL
:盛土
:切土

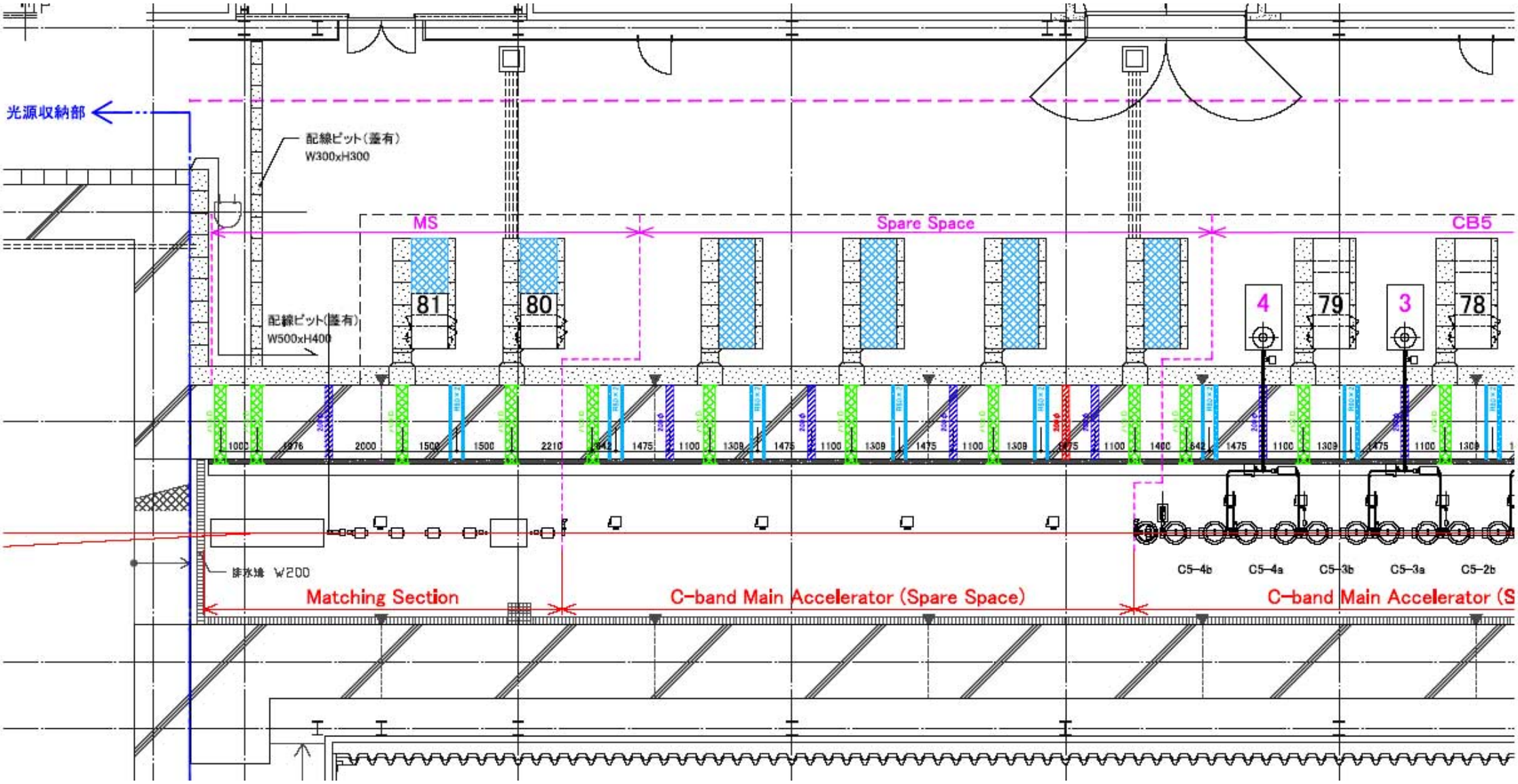

ンチラック等
配管立上り 700□xH400
埋設配管 φ100x2
水冷ラック据付
スペース
水冷ラックがない為、要追加
将来用スペース
(シーティング)
配線ピット(蓋有) W500xH400
クライストロンギャラリー
(装置セグメントS)
クリーントンネル（別途工事）
R450
配線ピット(蓋有)
W500xH400
マスターオシレーター
光伝送システム
3000x4500
H2500
82
BC1
INJ
迷路(L1)
目地B
配線ピット(蓋無) W300xH400
S-2a
S-1b
S-1a
非水槽（蓋有）
W200
非水槽
600□xH900
L-band APS 2
L-band APS 1
マシン収納部トンネル
Bunch Compressor BC1
Injector
目地B
※1500

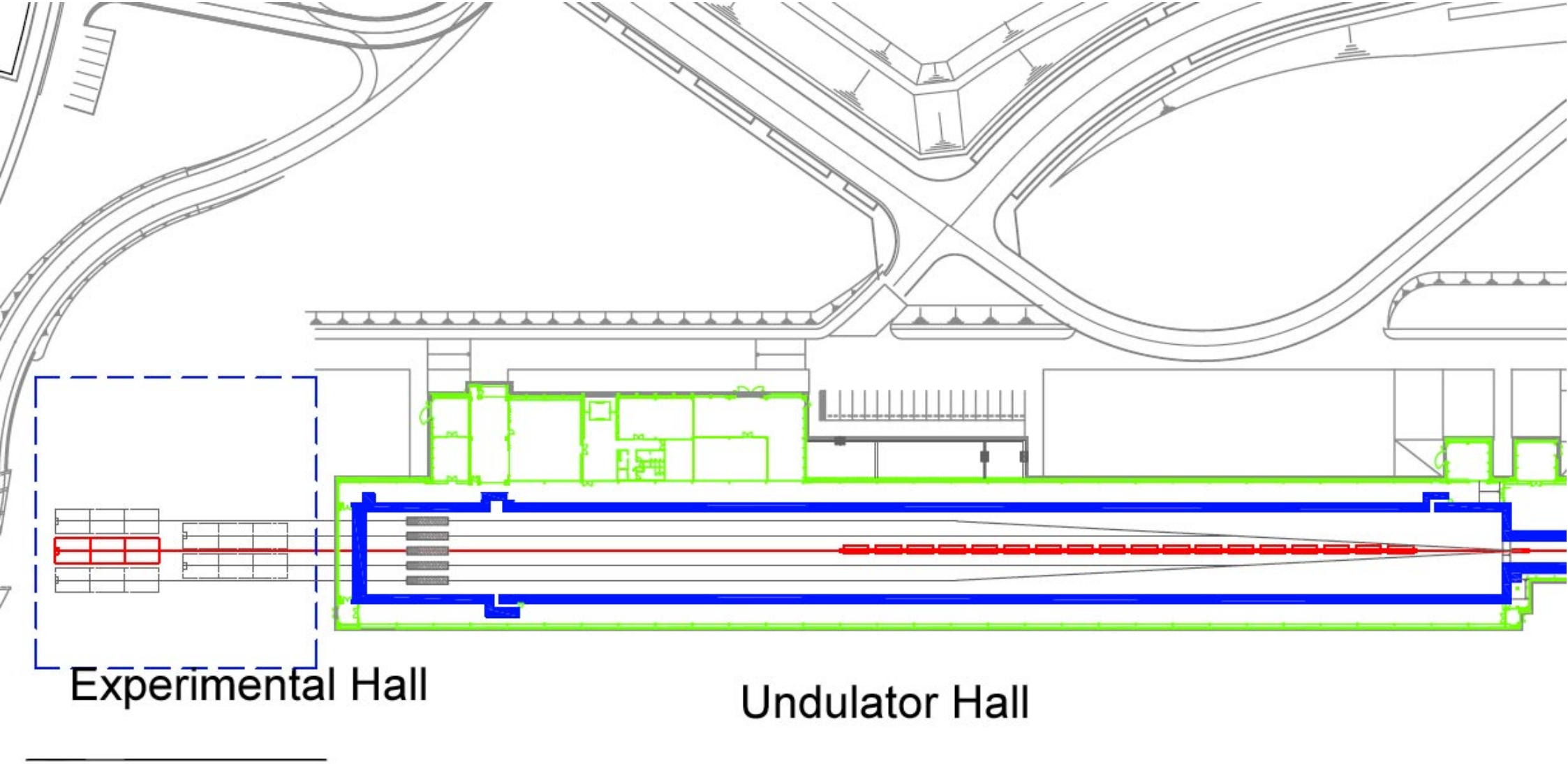

LAN-2
配線ピット(蓋有) W500xH400
配線ピット(蓋有):W500
配線ピット(ラック下は
1700x3000xH400
配線ピット(蓋有):W200
(装置セグメントC1)
R450
R450
将来用スペース
(シーディング)
BC2
14
2
13
1
12
11
10
7
9
6
配線ピット(蓋有)
W500xH400
1309
1475
1100
1309
1475
1100
2102
2000
3000
7000
3500
1600
2468
3664
2125
1100
1400
2455
2125
C1-2b
C1-2a
C1-1b
C1-1a
S-4b
S-4a
S-3b
Bunch Compressor BC2


内壁
CB1
12
23
11
22
10
21
9
20
8
19
7
18
6
17
5
16
4
15
3
14
C1-12b
C1-12a
C1-11b
C1-11a
C1-10b
C1-10a
C1-9b
C1-9a
C1-8b
C1-8a
C1-7b
C1-7a
C1-6b
C1-6a
C1-5b
C1-5a
C1-4b
C1-4a
C1-3b
C1-3a
C-band Accelerator (Section 1)


:セグメントC2)
RF-DEF
BC3
R450
R450
28
27
26
25
24
1
9
1475
1100
1400
1475
1100
1475
1100
3285
2000
3000
8100
2100
C2-1b
C2-1a
LOLA-7
LOLA-6
LOLA-5
LOLA-4
LOLA-3
LOLA-2
LOLA-1
C1-12
RF Deflector
Bunch Compressor BC3

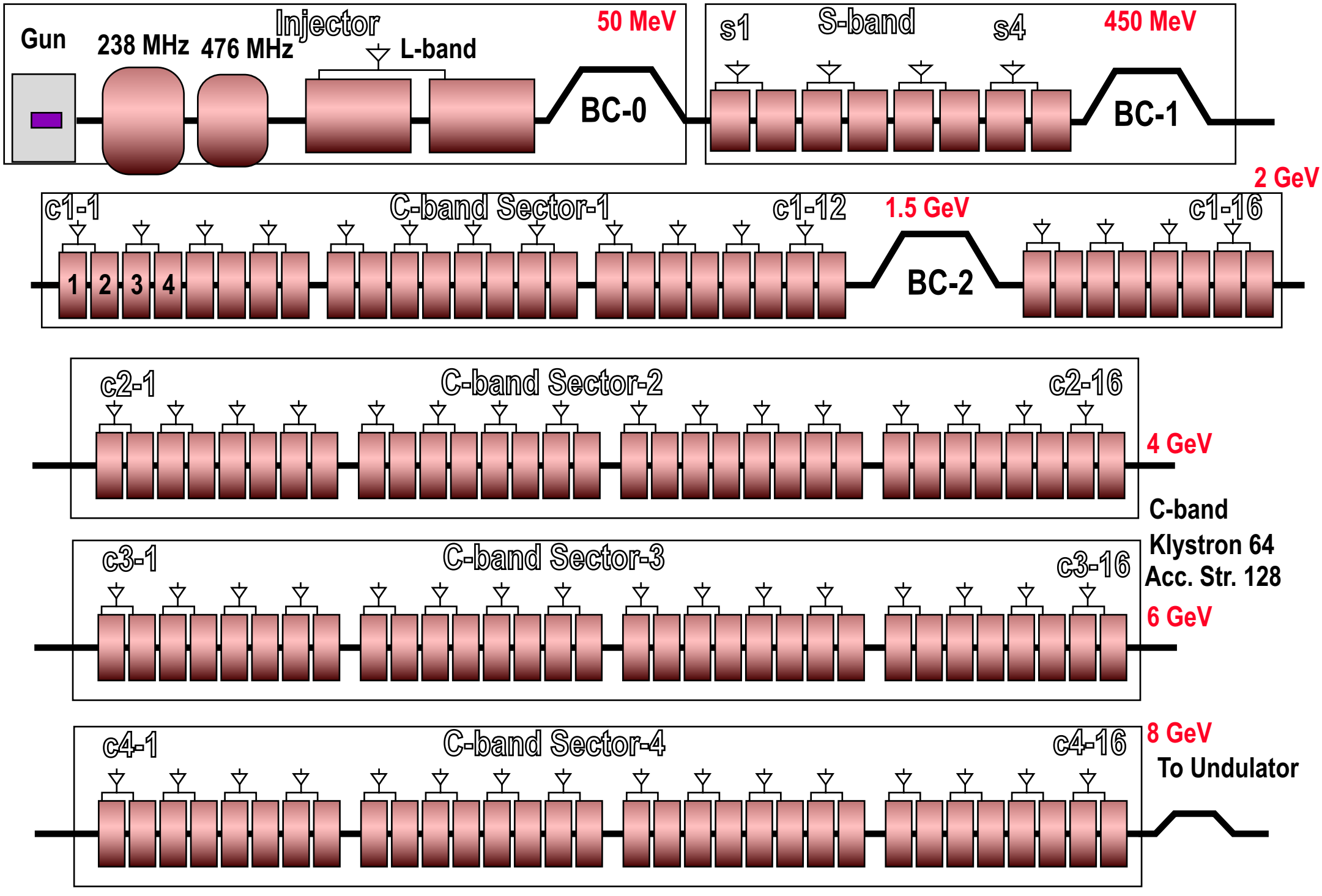

LAN-3
R450
CB2
(装置セグメ
11
38
10
37
9
36
8
35
7
34
6
33
5
32
4
31
3
30
2
29
1475
1100
1309
1400
842
1b
C2-11a
C2-10b
C2-10a
C2-9b
C2-9a
C2-8b
C2-8a
C2-7b
C2-7a
C2-6b
C2-6a
C2-5b
C2-5a
C2-4b
C2-4a
C2-3b
C2-3a
C2-2b
C2-2a
C2-1b
C-band Main Accelerator (Section 2)
1530
1200
3515
1400
1250
1150
200
1700
1200
迷路(L2)


光源収納部
配線ピット(蓋有)
W300xH300
配線ピット(蓋有)
W500xH400
MS
Spare Space
CB5
81
80
4
79
3
78
排水堰 W200
C5-4b
C5-4a
C5-3b
C5-3a
C5-2b
Matching Section
C-band Main Accelerator (Spare Space)
C-band Main Accelerator (S


Experimental Hall
Undulator Hall

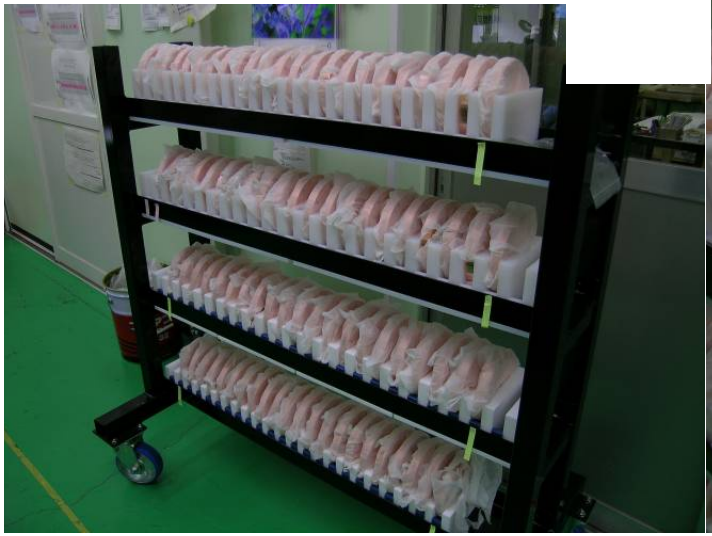
RF Acceleration System in 8 GeV SPring-8 XFEL

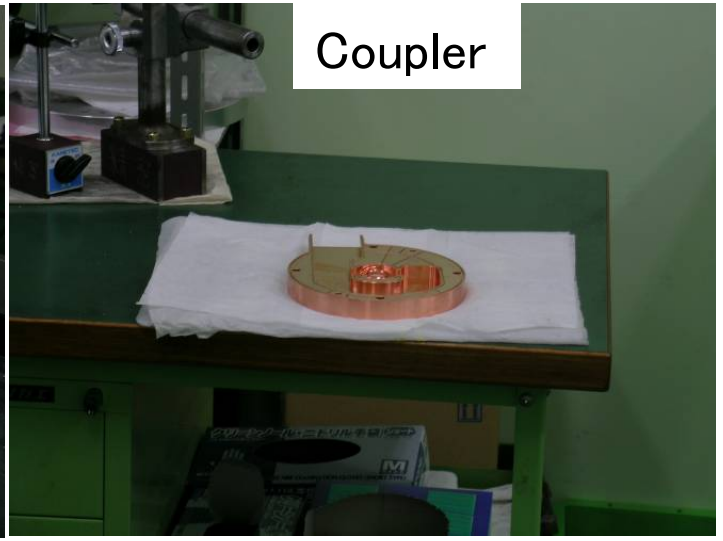
T.Shintake 2007 March

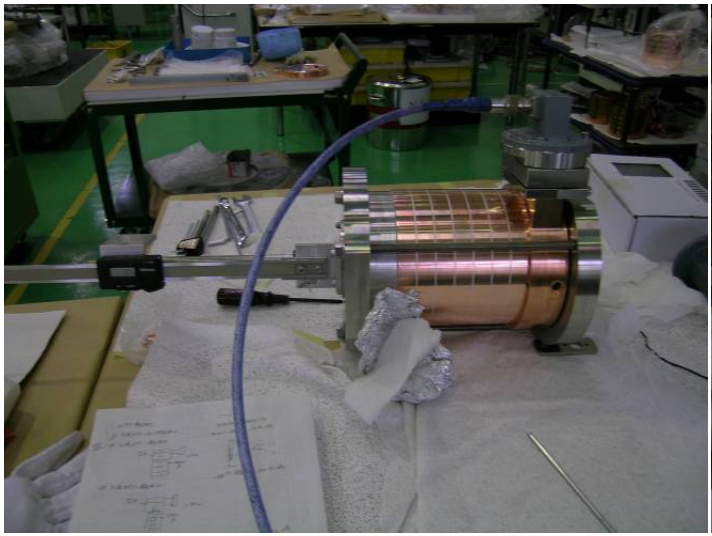


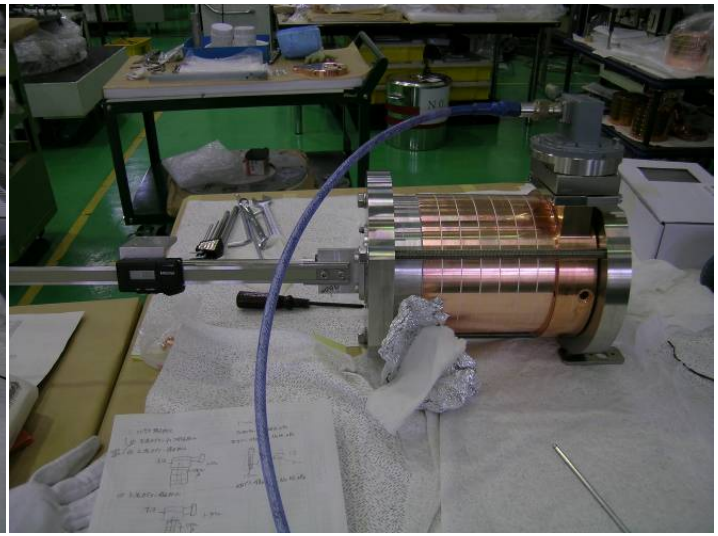
Acc. Mass Production, July 20

Cells for C-band Choke Mode Cavity No. 0

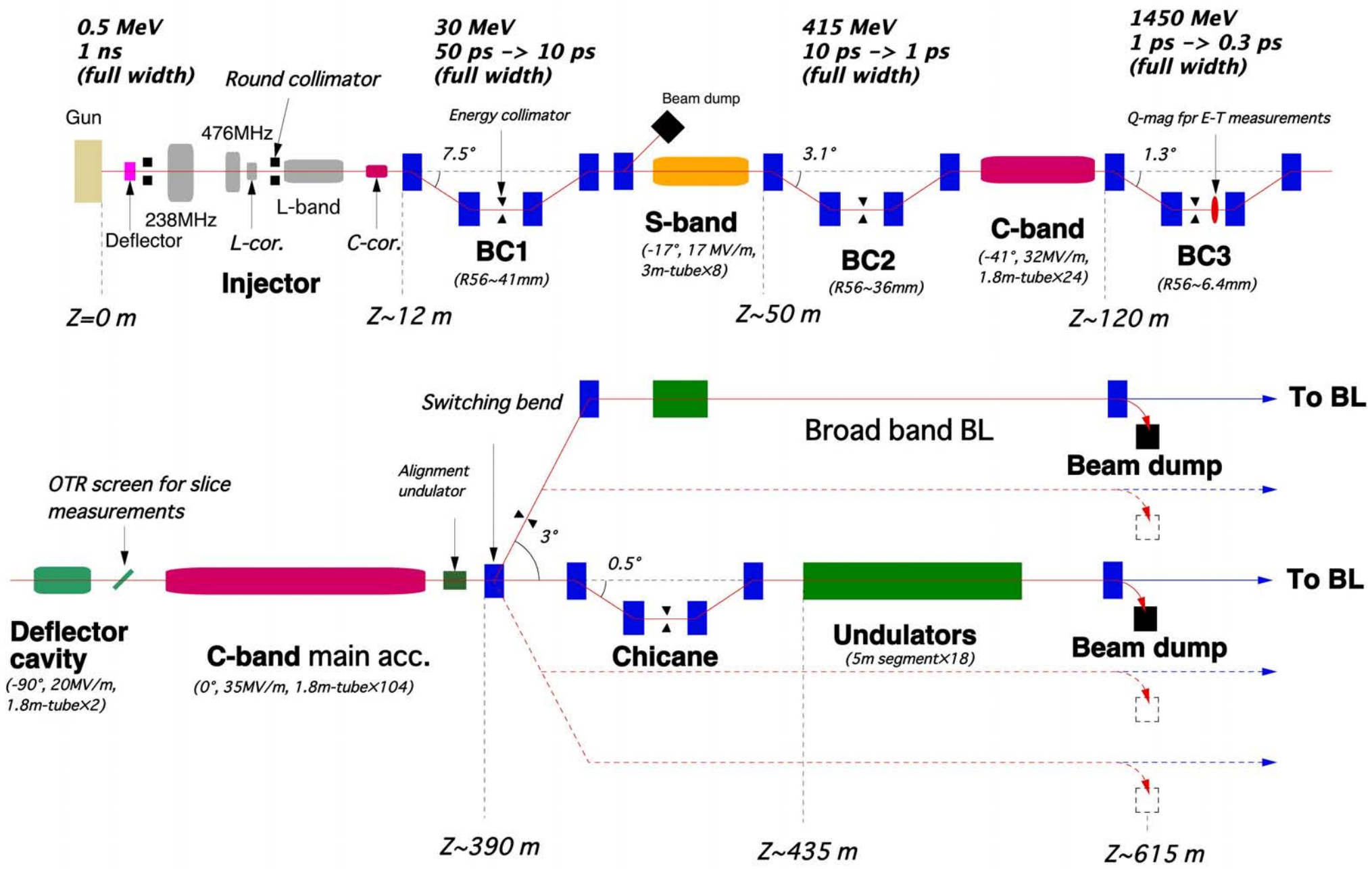








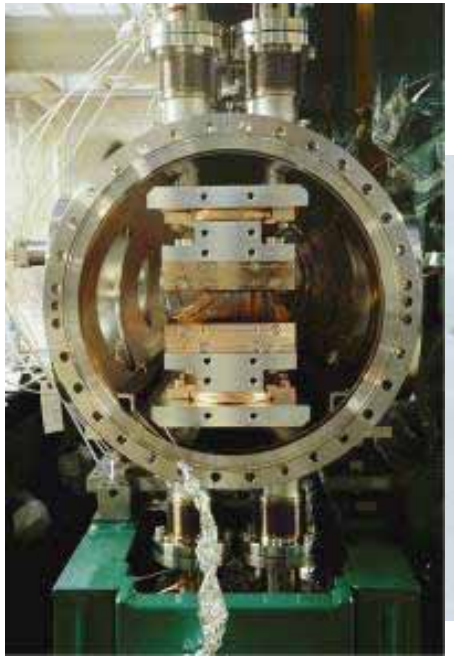
Coupler Matching Test


0.5 MeV
1 ns
(full width)
Round collimator
Gun
476MHz
238MHz
Deflector
L-cor.
L-band
C-cor.
Injector
Z=0 m
30 MeV
50 ps -> 10 ps
(full width)
Energy collimator
7.5°
BC1
(R56~41mm)
Z~12 m
Beam dump
S-band
(-17°, 17 MV/m,
3m-tube×8)
415 MeV
10 ps -> 1 ps
(full width)
3.1°
BC2
(R56~36mm)
Z~50 m
C-band
(-41°, 32MV/m,
1.8m-tube×24)
1450 MeV
1 ps -> 0.3 ps
(full width)
Q-mag fpr E-T measurements
1.3°
BC3
(R56~6.4mm)
Z~120 m
Switching bend
Broad band BL
To BL
Beam dump
OTR screen for slice
measurements
Alignment
undulator
3°
0.5°
To BL
Deflector
cavity
(-90°, 20MV/m,
1.8m-tube×2)
C-band main acc.
(0°, 35MV/m, 1.8m-tube×104)
Chicane
Undulators
(5m segment×18)
Beam dump
Z~390 m
Z~435 m
Z~615 m

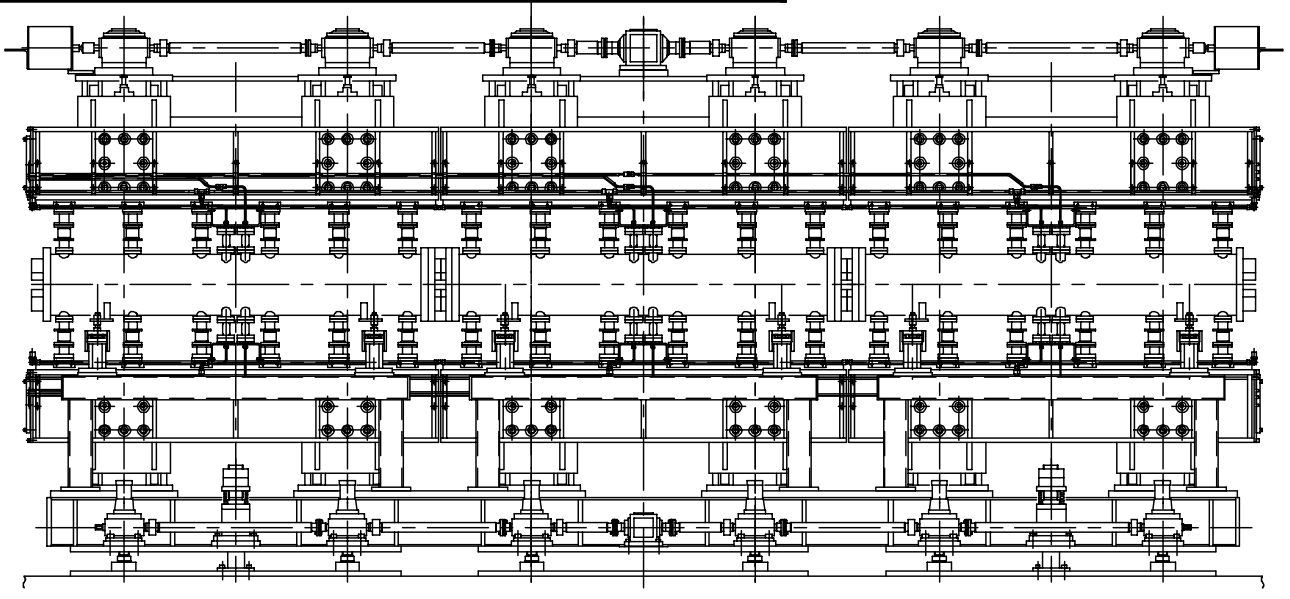
Undulator for XFEL/SPring-8

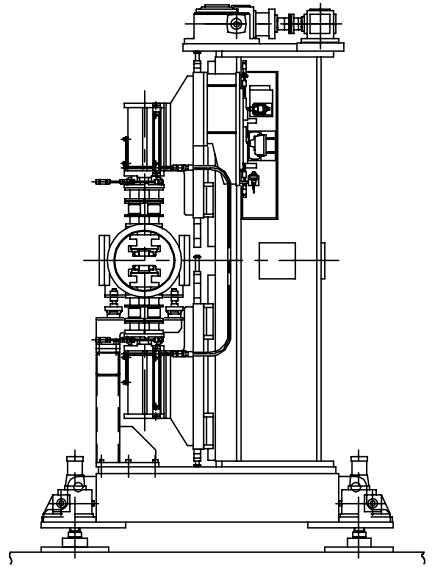
Takashi Tanaka

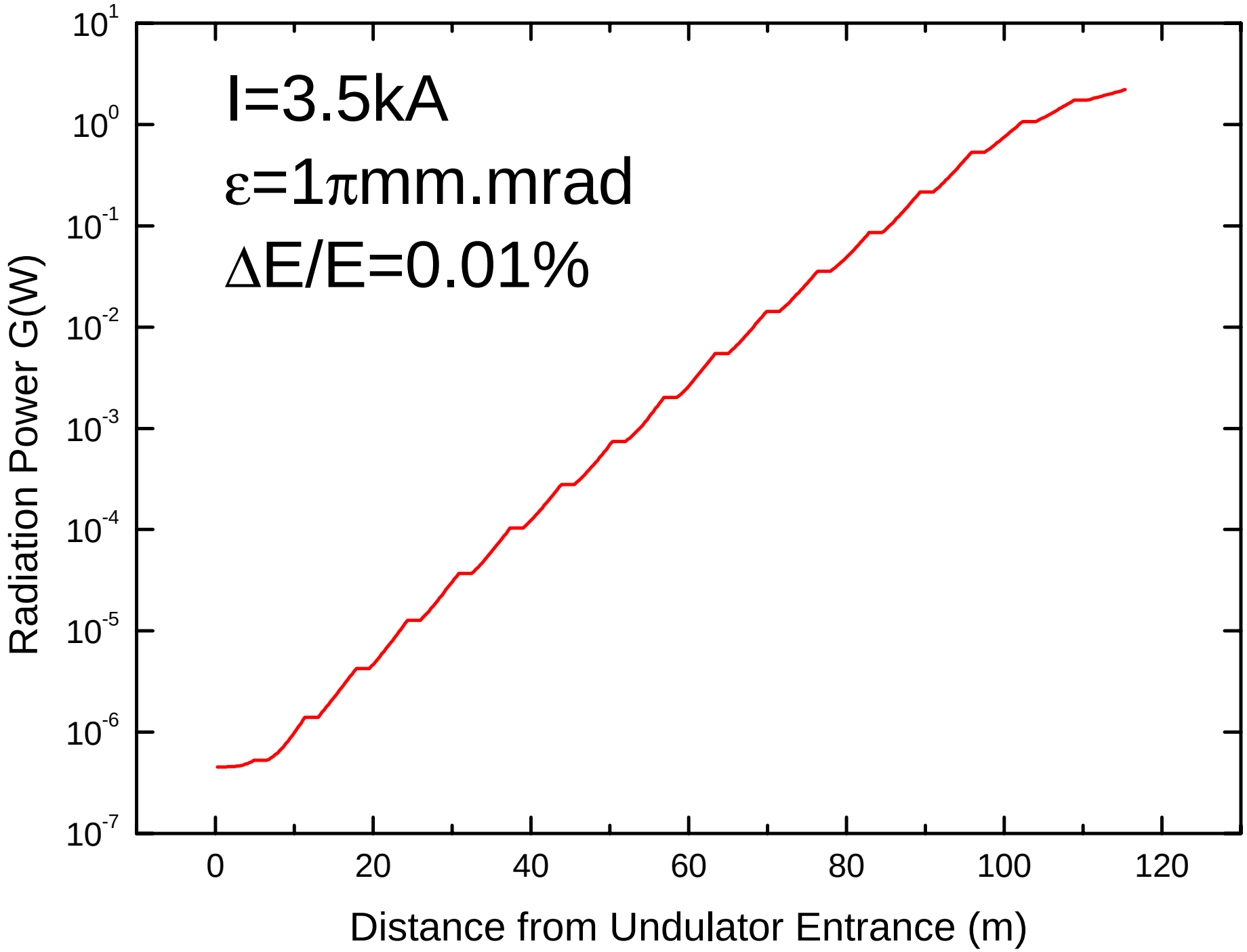
Magnetic Circuit		Hybrid
Length		5 m
Period		18mm
Number of Periods		276
Gap	Minimum	2mm
	At 1Å ope	4mm
	Max	40mm
K-value	Max	2.1
	At 1Å ope	1.9



NeFeB Hybrid



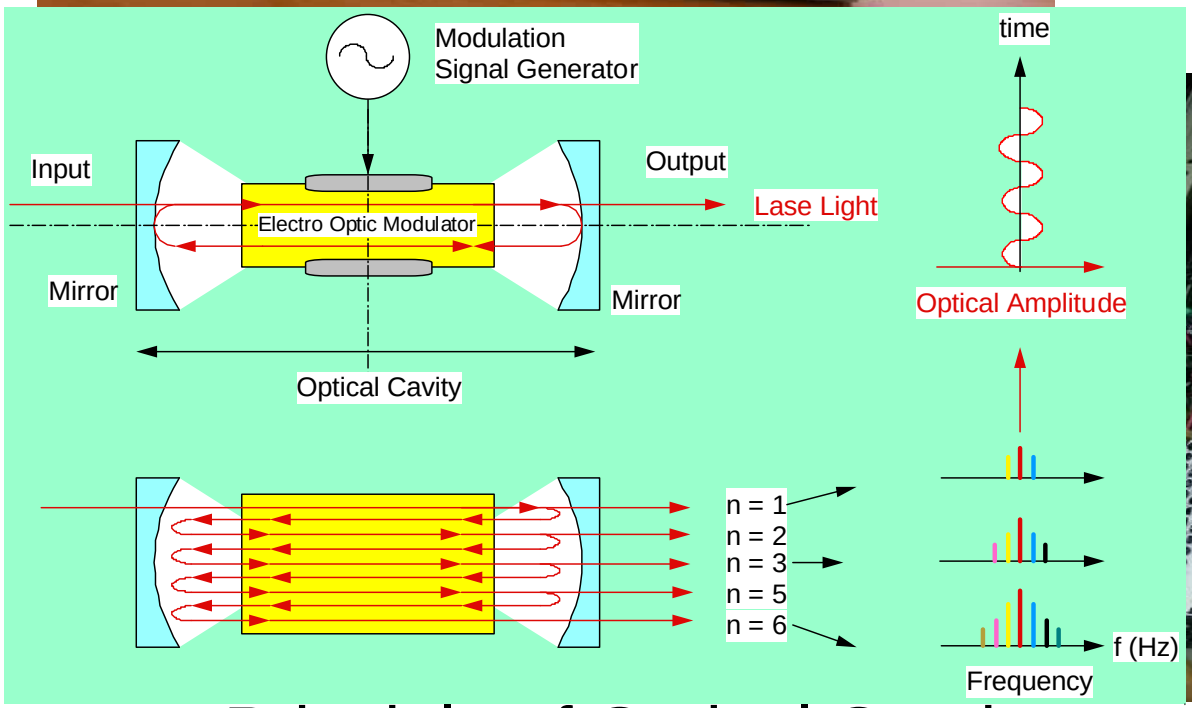



I=3.5kA
ε=1πmm.mrad
ΔE/E=0.01%
Radiation Power G(W)
Distance from Undulator Entrance (m)
10^1
10^0
10^-1
10^-2
10^-3
10^-4
10^-5
10^-6
10^-7
0
20
40
60
80
100
120

Optical Comb Generator as RF Optical Modulator

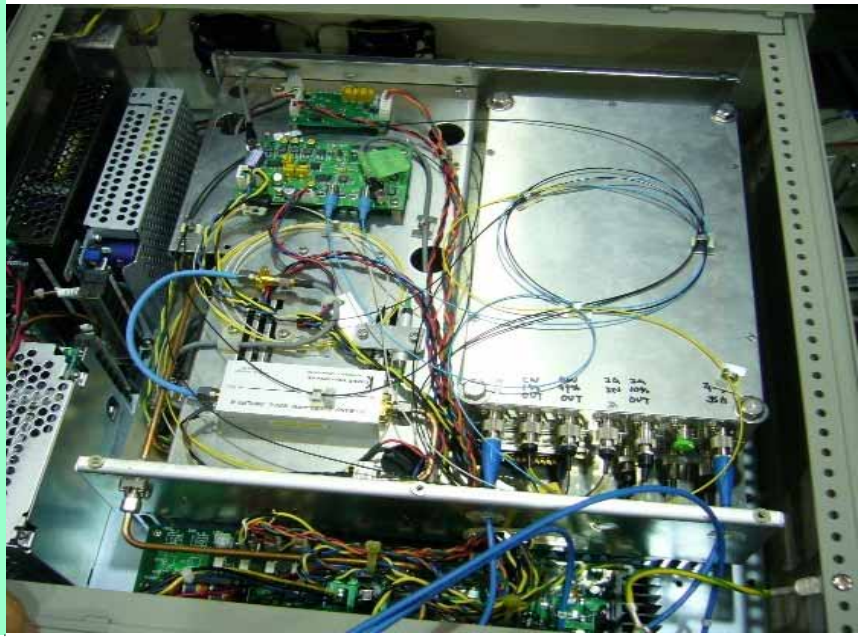
Y. Otake

DFB Solid State Laser looked to Acetylene Absorption Spectrum (1538 nm)



Principle of Optical Comb

Inside of Optical Comb

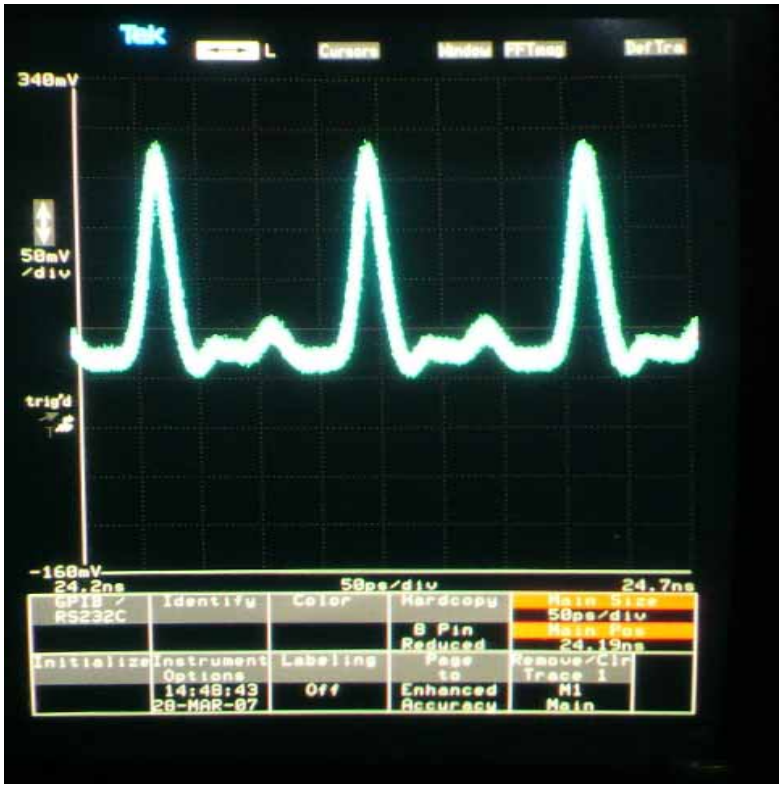


Optical Output of Optical Comb Generator

Driven by Master Oscillator (5712 MHz)

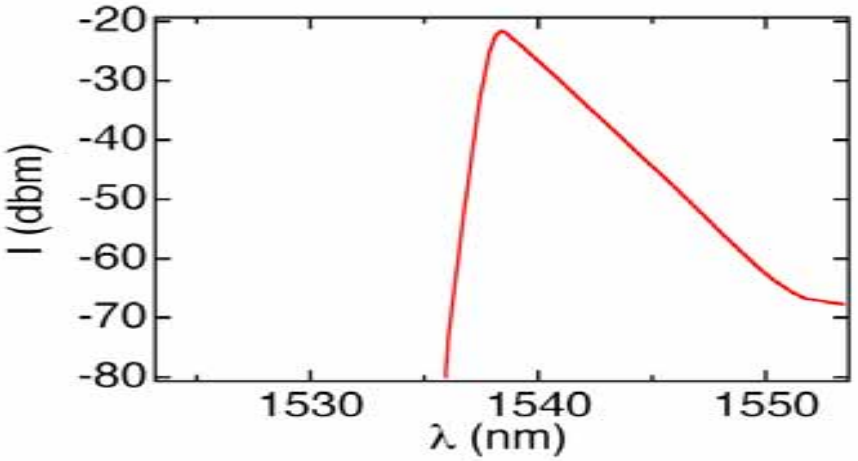
Y. Otake

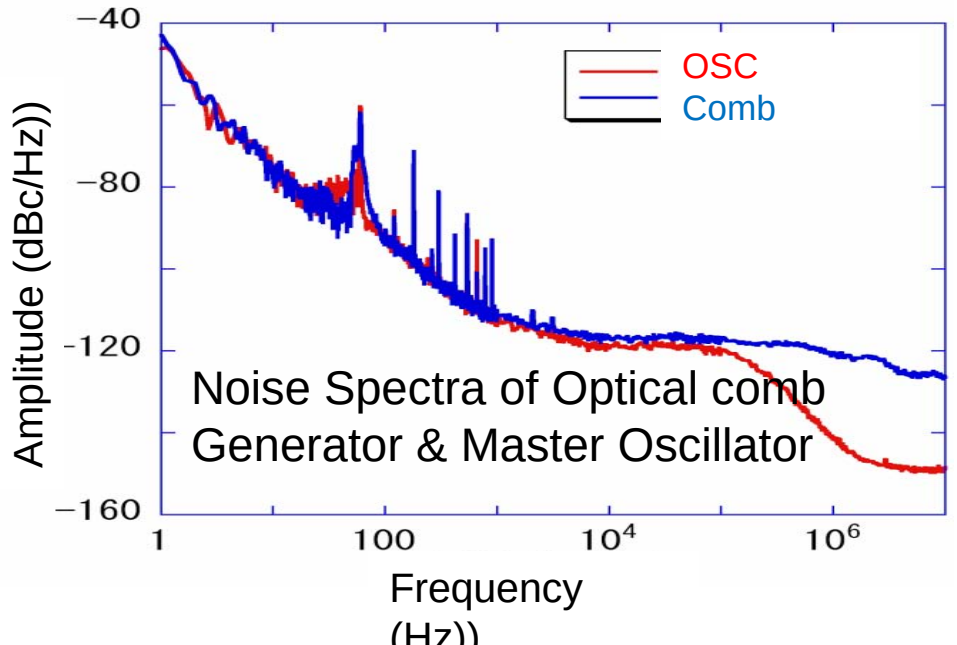
175 ps



Wave Form of Optical Comb

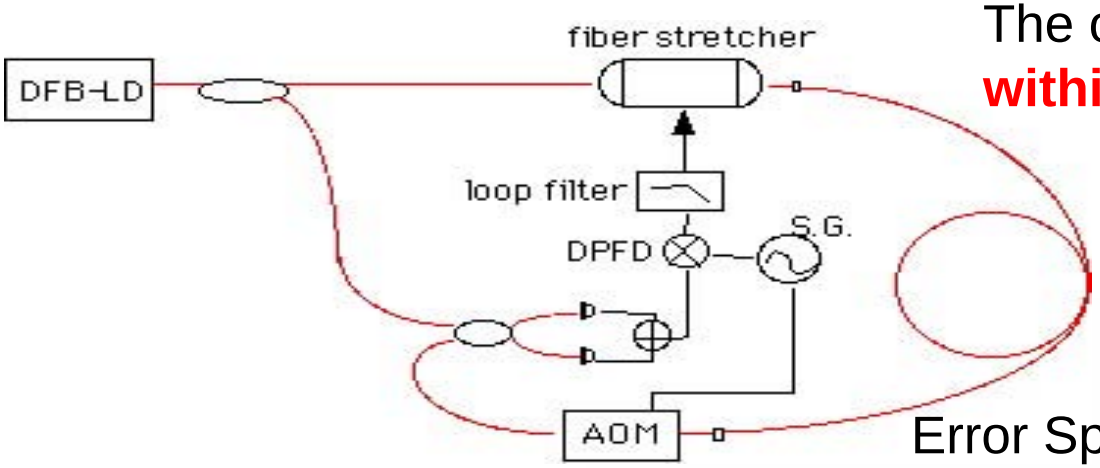
Spectrum of Comb Light (Envelope)





Experiment for Optical Fiber Length Control

Y. Otake

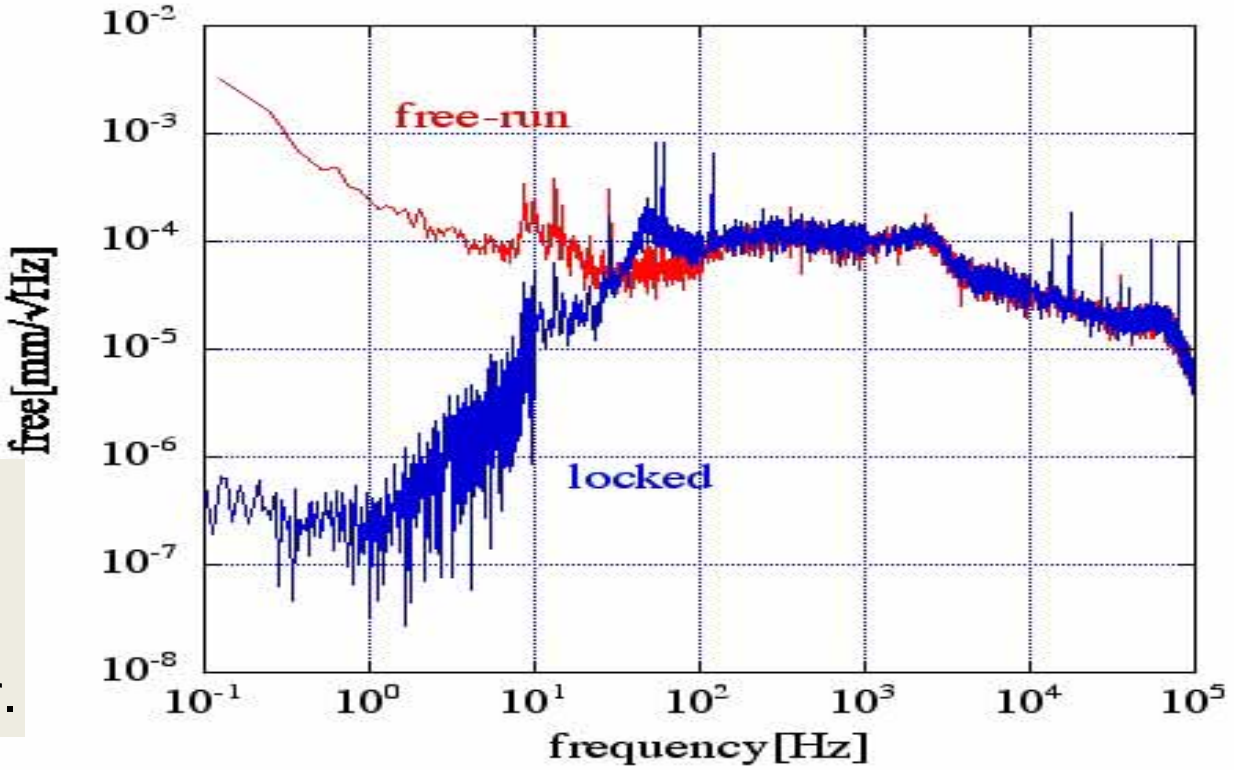


The optical fiber length was controlled **within 3 μm for 2km** long.

fs time stability

Experimental set up

Error Spectra of Fiber Length Feedback Control



This experiment was carried out by using a 1 km phase stabilized optical fiber laid in the Spring-8 ring accelerator.

First Lasing at SCSS Prototype Accelerator.

Use'r Experimental Room has been build

New Exp. Hall

X-ray beam pipe

User run will start in October 2007

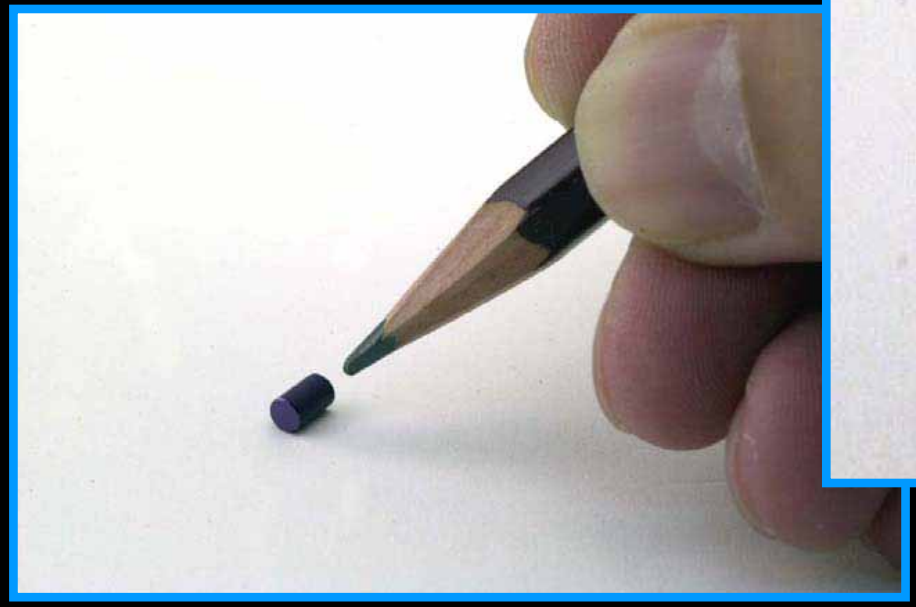
What learned from SCSS Test Accelerator

- **CeB_6 thermionic cathode is very stable and long life**. One and half year after installation, it's still OK.
- After stabilizing RF power supply and cavity temperature, **SASE lasing became very stable**.
- Measurement on **arriving time jitter showed only 50 fs** jitter. Bunching process (x100~x400) is fairly stable.
- **Collimator is important** to stabilize lasing.
  - Collision less bunching.

CeB_6 Cathode & Heater Assembly

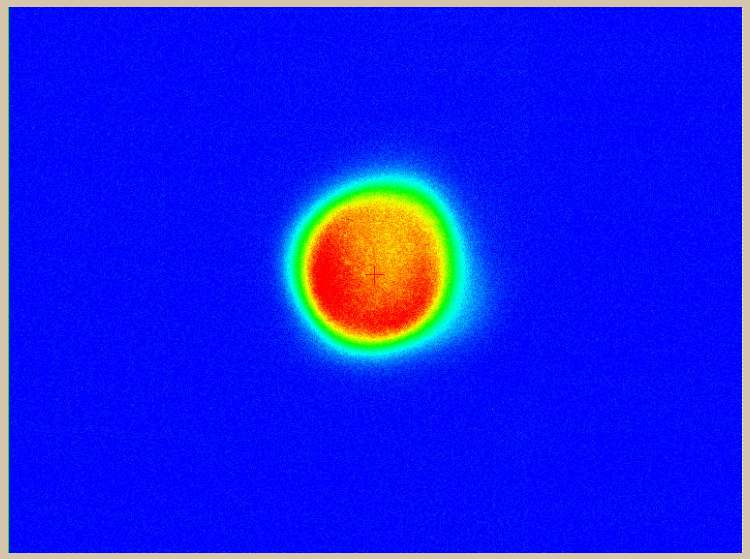
X-ray FEL

- CeB_6 Cathode 3 mm Diameter
- Emittance 0.4 π.mm.mrad
  (thermal emittance, theoretical)
- Beam Current 3 Amp.
  at 1450 deg.C
  (using graphite heater)
- Current Density > 40 A/cm^2

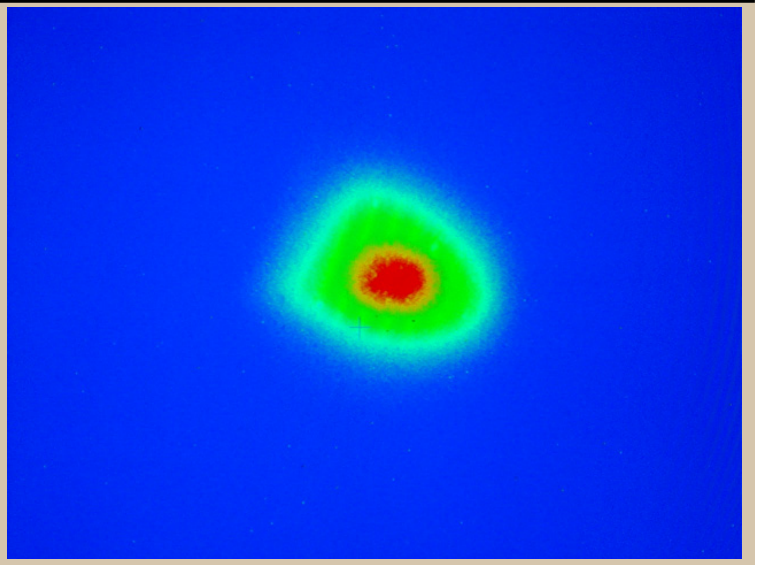


CeB_6 Thermionic Gun provides stable beam.

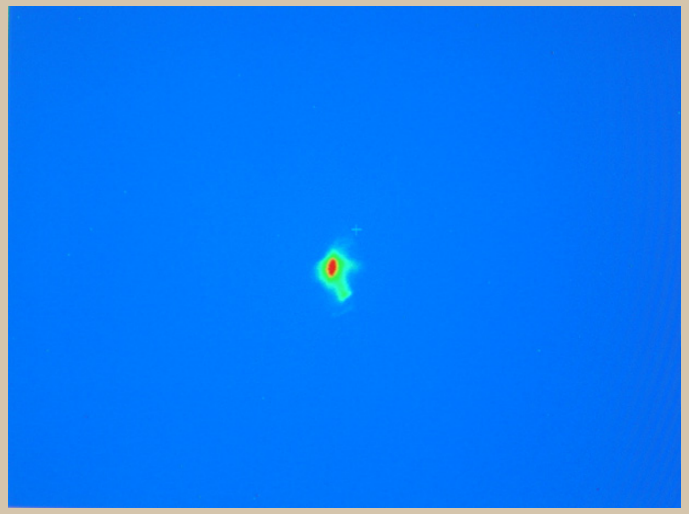
Beam Profile
CCD Image
Scale 10 mm



500 kV Gun



50 MeV Injector Out

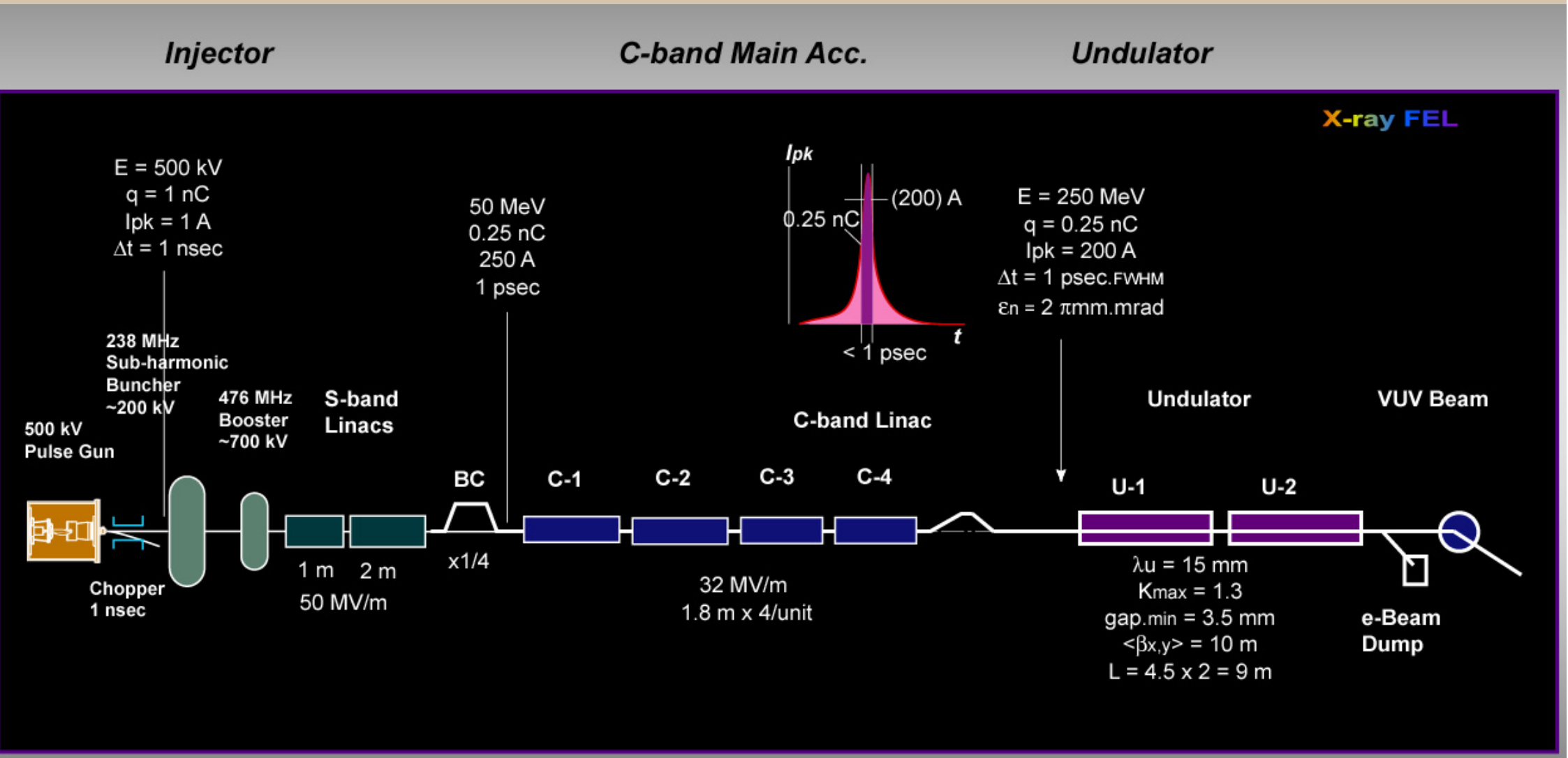


250 MeV Compressor

Undulator Input

Undulator Output

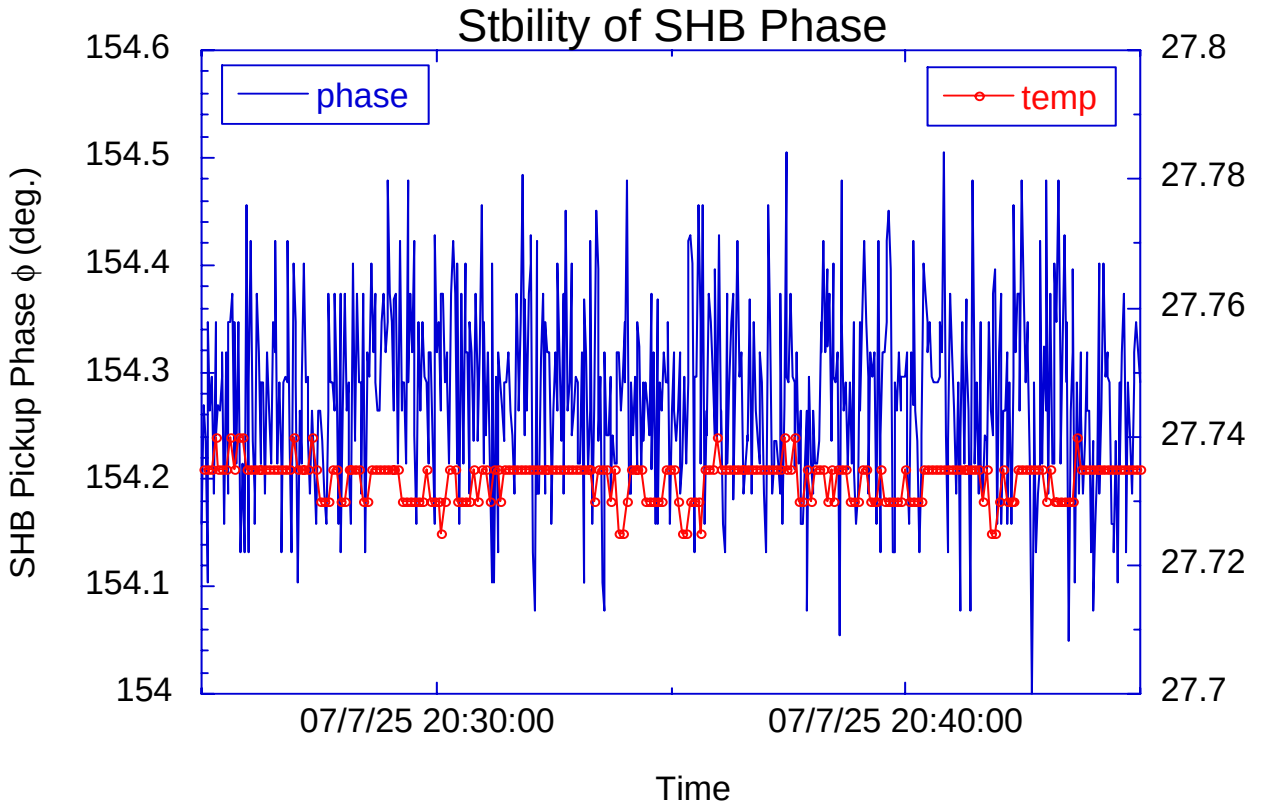
Test Accelerator Layout

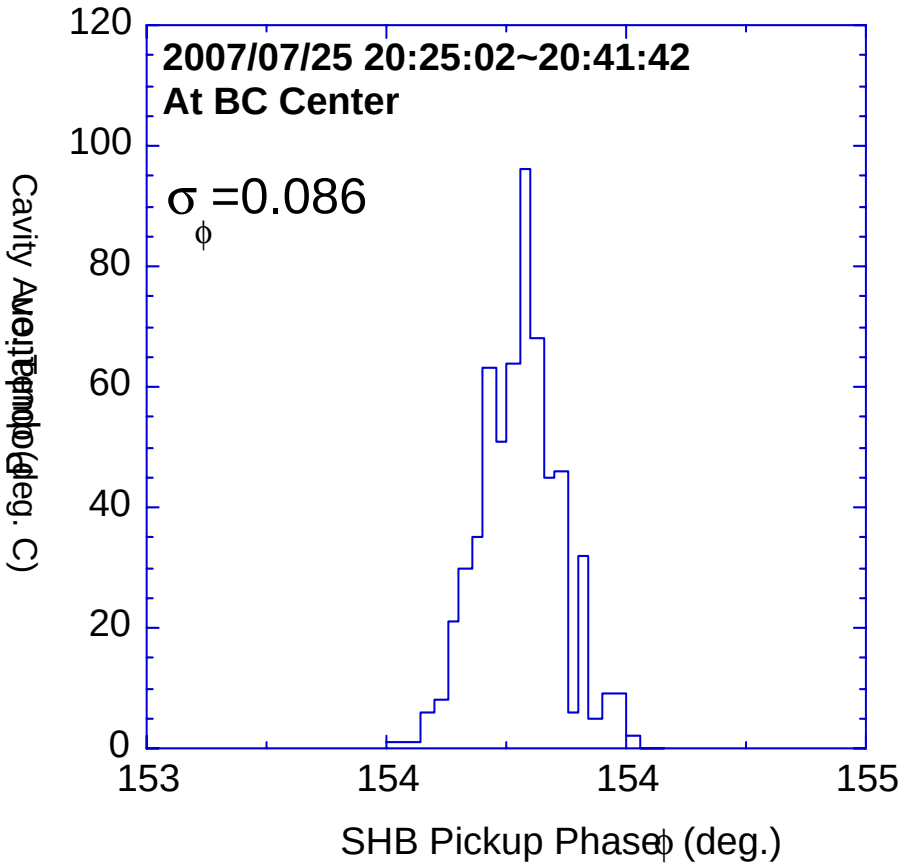


Temperature Control on Sub-Harmonic Buncher Cavity

- Upstream **238 MHz Sub-harmonic buncher** cavity provide **time base** in this accelerator.
- It has same function as "**Mode-locker**" in the laser system→ **time base**.
- Stability of this cavity dominate system performance.
  → Cavity body is made by **"Massive Copper",** which **eliminates jitter**.
- Using **electric heater**, **the inlet water temperature is controlled at constant**.

Stability of Injector RF System

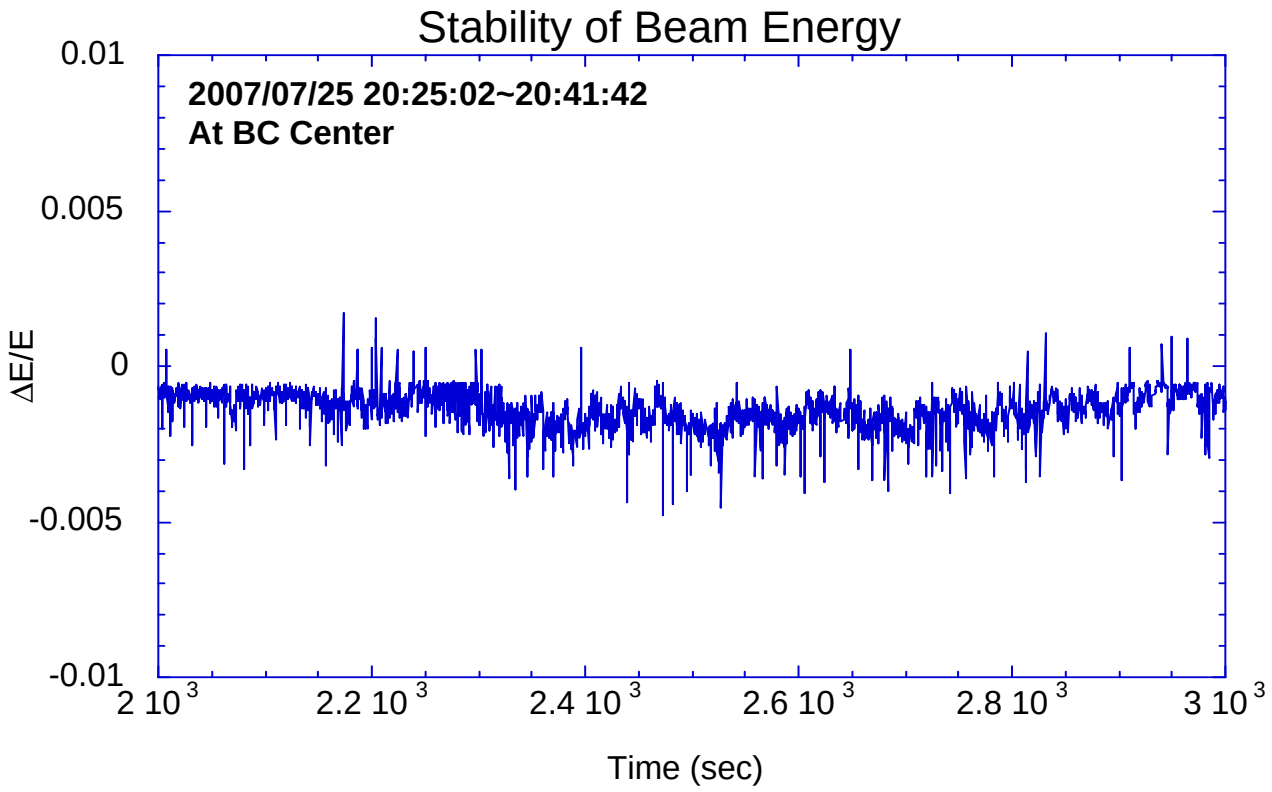


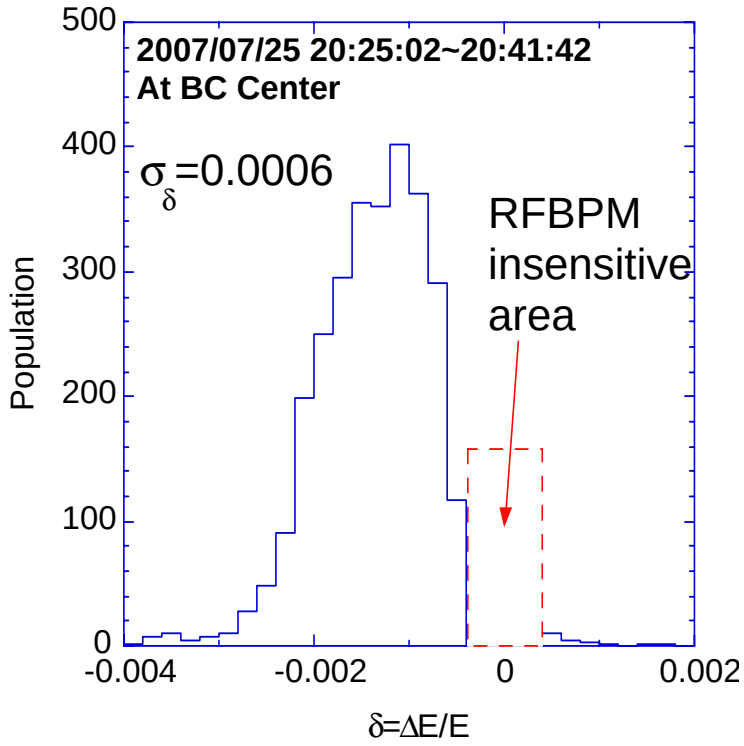


Phase Jitter = 0.086 deg. at 238 MHz (10 minute)

→ Cavity Temperature Fluctuation < 0.1 mK

Stability of Beam Energy

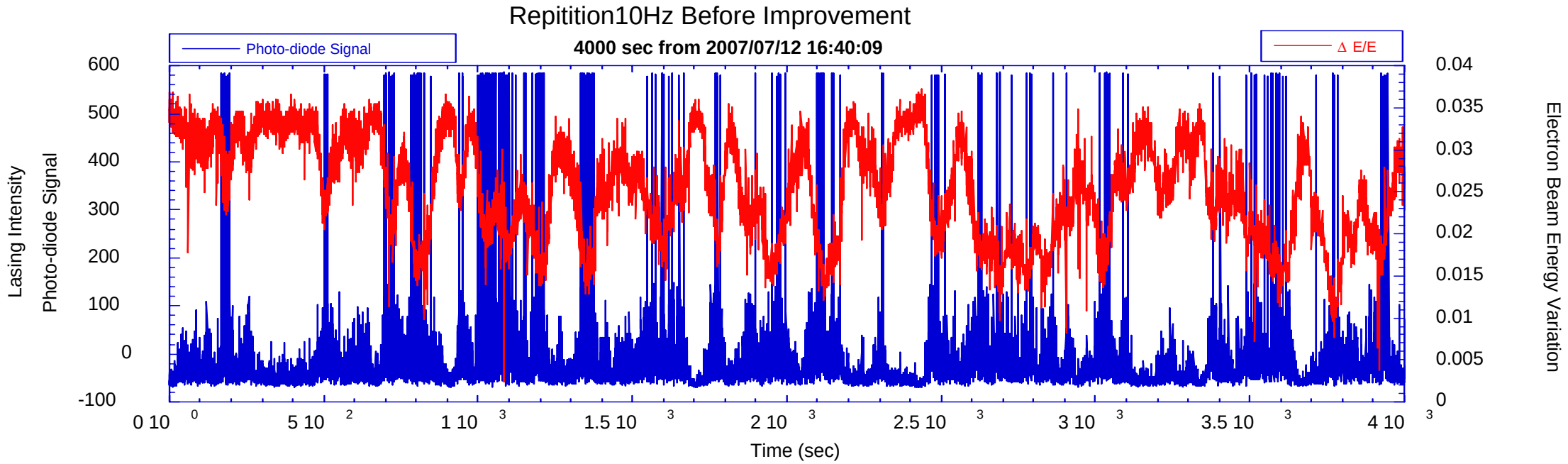


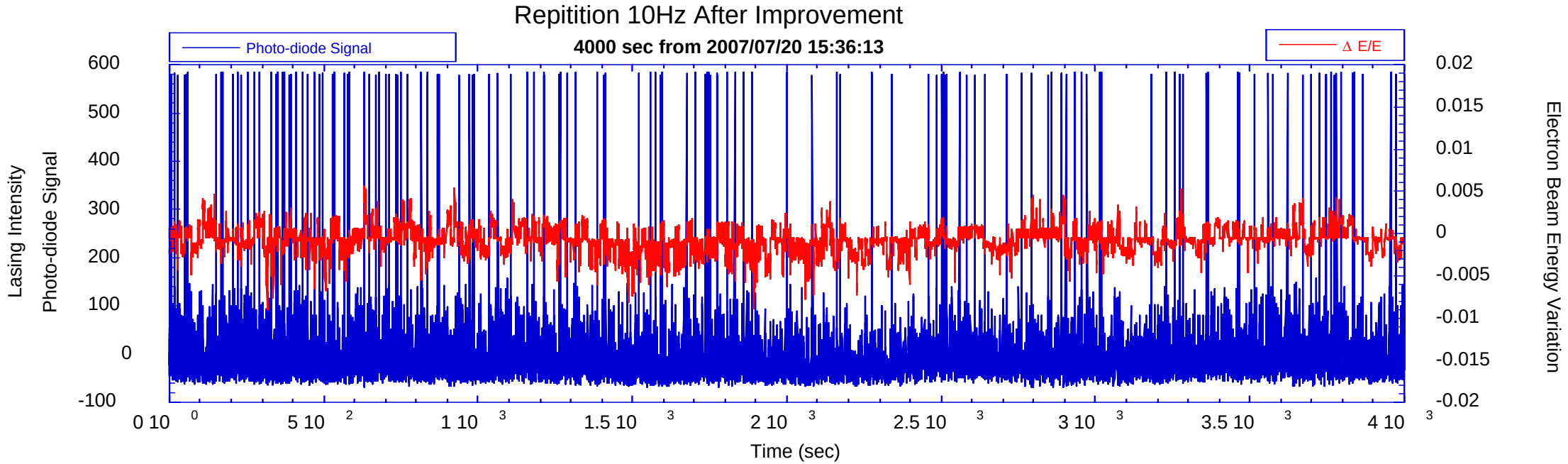


$\delta E/E \sim 6 \times 10^{-4}$ (20 minute)

without RF Feedback on SHB and booster cavity.

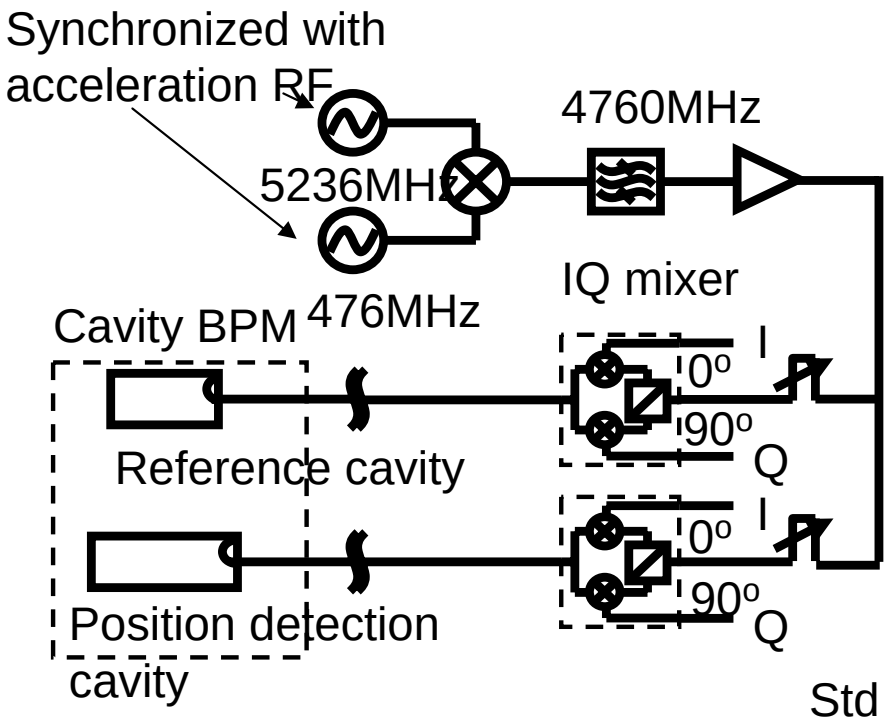
Stability of Lasing





Beam Arriving Time Jitter Measurement

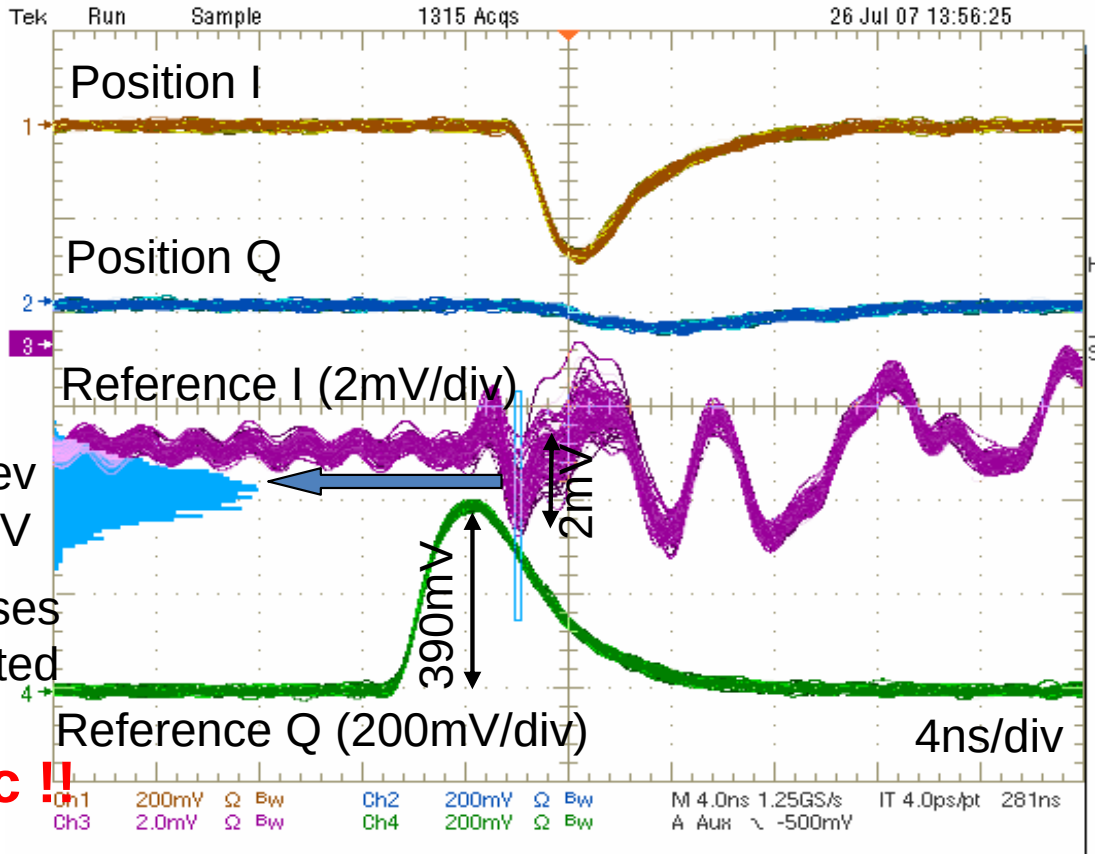
The Block Diagram of the Beam Jitter Detection System



Reference Cavity Amplitude (I Signal): 390 mV

Reference Cavity Amplitude (Q Signal): 0.54 mV

0.54mV (1 **σ**) ⇒ 0.54/390=1.38mrad



Std Dev 0.54mV

~1300pulses accumulated

Arriving Time Jitter:

1.38mrad / 4760MHz / 2π = 46 fsec !!

Schedule & Summary

- **User run will start in October 2007 at SCSS Prototype Accelerator**

- **Mass production for 8 GeV main linac has started.**
- **Mass production of undulator will start in 2008**
- **Civil construction will end April 2009.**
- **Installation : 2009-2010**
- **First X-ray beam : End of FY 2010**

Thank you very much!