

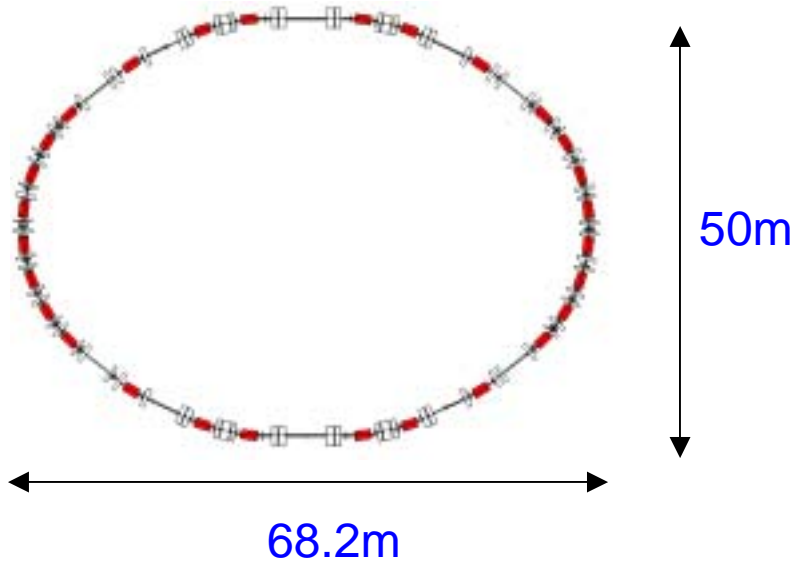
# PF, PF-AR and PF-ERL

What's difference  
between  
SR rings and ERLs?

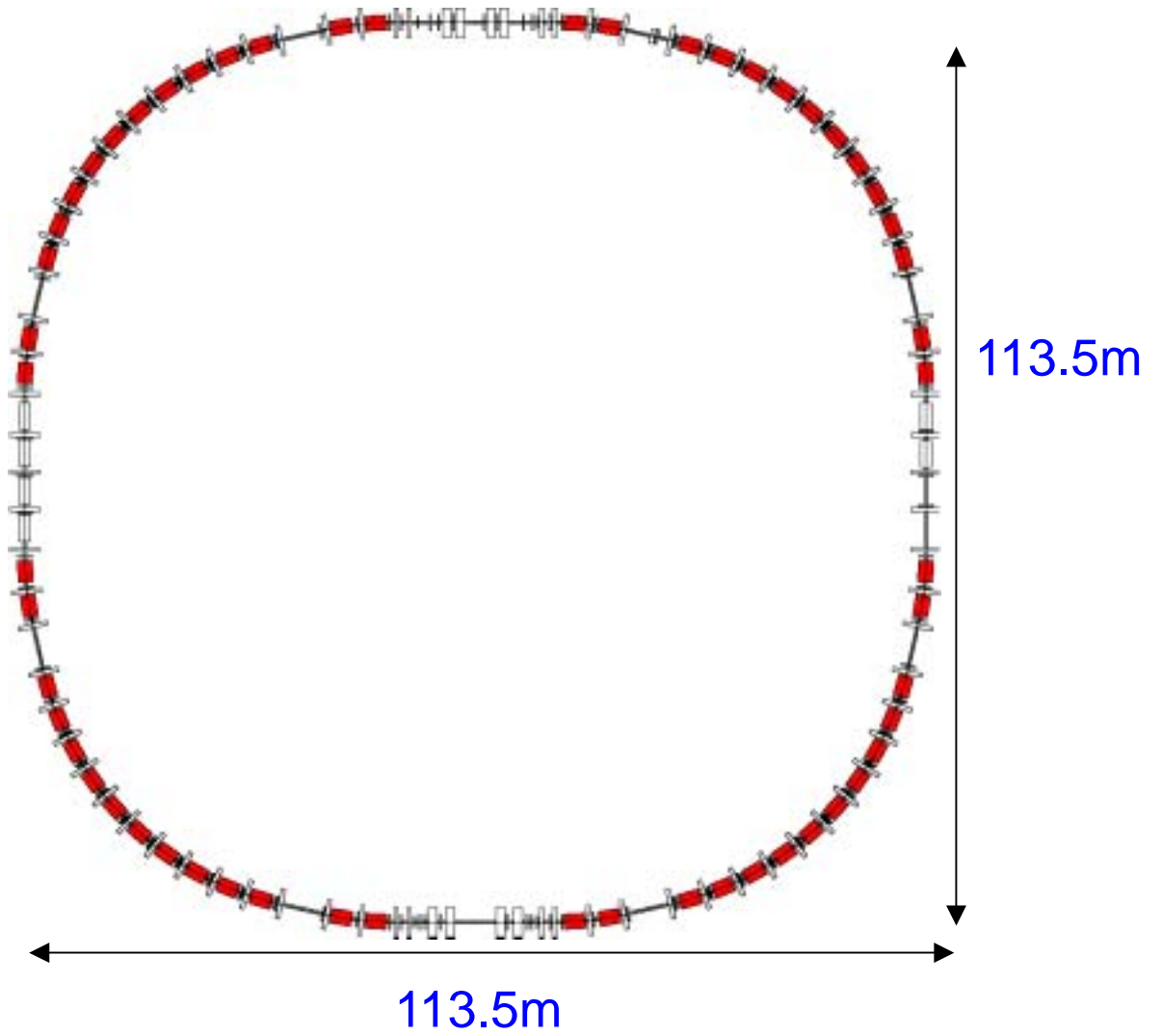
This is **KEK**



PF



PF-AR



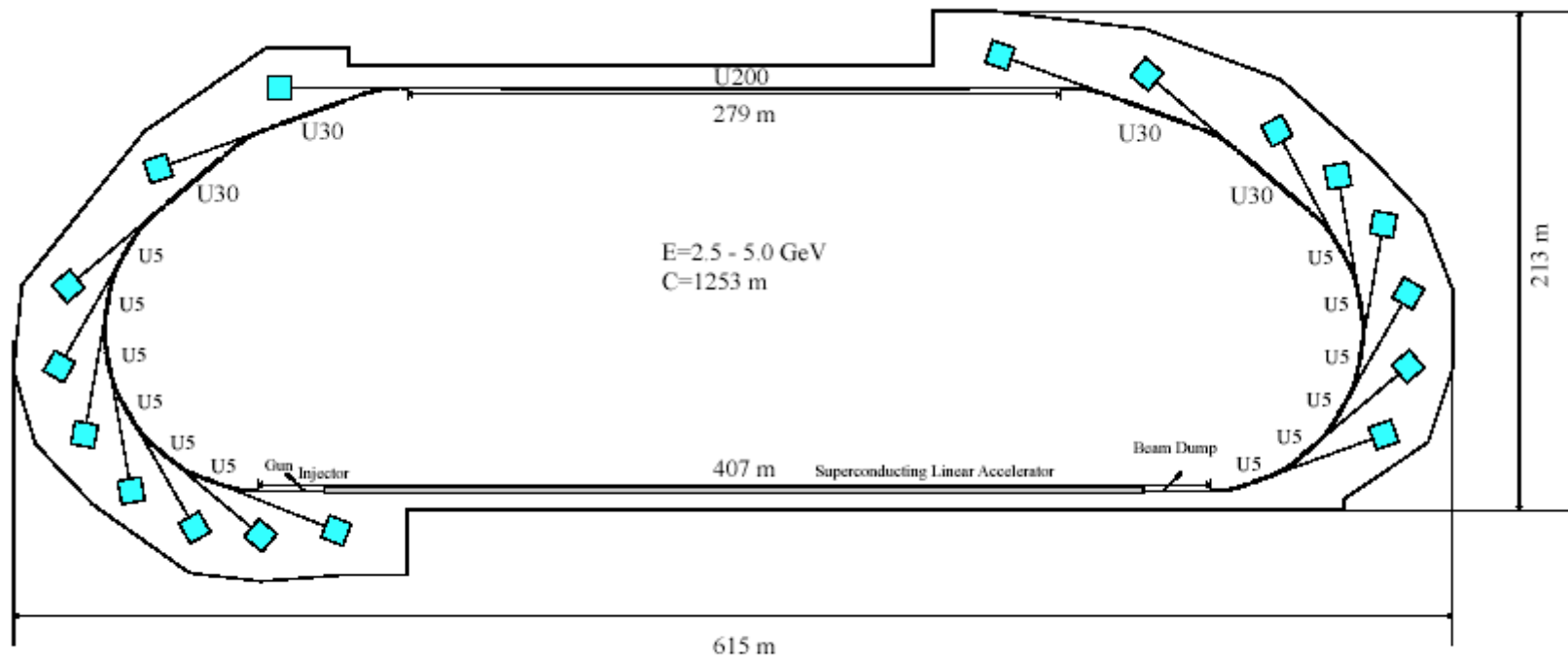
## Parameters of PF & PF-AR Ring

		PF	PF-AR
Energy	E [GeV]	2.5	6.5
Circumference	C [m]	187.07	377.26
Emittance	$\epsilon_0$ [nm × rad]	35.78	295.17
Energy Spread	$\sigma_E/E$	7.28474E-04	1.14586E-03
Momentum Compaction	$\alpha$	6.16870E-03	1.27625E-02
Betatron Tune			
horizontal	$\nu_x$	9.66	10.15
vertical	$\nu_y$	4.25	10.19
Synchrotron Tune	$\nu_s$	0.0142295	0.0567625
Chromaticity			
horizontal	$\xi_x$	-12.570	-14.250
vertical	$\xi_y$	-11.529	-13.159
Energy Loss	$U_0$ [keV/rev.]	398.853	6660.751
Damping Time			
horizontal	$\tau_x$ [msec]	7.787	2.454
vertical	$\tau_y$ [msec]	7.822	2.457
longitudin	$\tau_z$ [msec]	3.921	1.230
Revolution Frequency	$f_{rev}$ [MHz]	1.60253	0.79466
RF Frequency	$f_{RF}$ [MHz]	500.100	500.100
Harmonic Number	h	312	640
RF Voltage	$V_{RF}$ [MV]	1.70	17.30
Bunch Length	$\sigma_z$ [mm]	9.40128	15.40534
RF Bucket Height	$(\Delta E/E)_{RF}$ [%]	1.217590	0.992220

## PF-ERL Main Parameters

Beam Energy	2.5 ~ 5.0 (GeV)
Injection Energy	10 (MeV)
Circumference	1253 (m)
Beam Current	~100 (mA)
Normalized Emittance	~0.1 (mmrad)
Horizontal Emittance	~10.0 (pmrad) at 5.0 GeV
Vertical Emittance	~10.0 (pmrad) at 5.0 GeV
Energy Spread	~5x10 <sup>-5</sup>
Bunch Length	1 (ps) ~ 100 (fs)
RF Frequency	1.3 (GHz)
ACC. Gradient	~20 (MV/m)
Long Undulator	200 (m) x 1
Middle Undulator	30 (m) x 4
Short Undulator	5 (m) x12

# PF-ERL Project



## What's difference between ERL and SR ring?

### 1、 Beam Loading of LINAC

#### KEKB LINAC (injector for KEKB, PF & AR)

- pulsed operation

RF macropulse 1 $\mu$ Sec 50Hz

single to several bunch in one macropulse

- bunch current

When 0.1nC/bunch (typical value for normal operation) is injected without any loss, injection rates become

PF  $f_{\text{LINAC}}=12.5\text{Hz}$ 、  $f_{\text{rev}}=1.2\text{MHz}$ :

$$0.1 \times 10^{-9} \times 12.5 \times 1.2 \times 10^6 = 1.5 \text{mA/Sec}$$

AR  $f_{\text{LINAC}}=25.0\text{Hz}$ 、  $f_{\text{rev}}=0.8\text{MHz}$ :

$$0.1 \times 10^{-9} \times 25.0 \times 0.8 \times 10^6 = 2.0 \text{mA/Sec}$$

- When bunch current is 1nC, beam loading is

$$1\text{nC} \times 50\text{Hz} \times 8\text{GeV} = 50\text{nA} \times 8\text{GeV} = 400\text{W}$$

#### ERL

- continuous (CW, so called,) operation

RF is not pulsed.

all micropulses (1.3GHz) filled with bunches.

- bunch current

$$77\text{pC/bunch} \times 1.3\text{GHz} = 100\text{mA}$$

- beam loading become

$$100\text{mA} \times 5\text{GeV} = 500\text{MW}$$

c.f. electric power consumption in KEK

KEKB 43MW, PF 5MW, AR 6MW, LINAC 3MW

## 2、 frequency of photon beam

### Storage Ring

	PF	AR
number	280 / 312	1 / 640
revolution frequency (MHz)	1.603	0.795
current (mA)	400	50
bunch current (mA)	1.4286	50
bunch charge (nC)	0.8914	62.9201

### ERL

1.3GHz, 100mA, 77pC/bunch

## 3、 emittance, bunch length

Emittance, energy spread, bunch length etc.. are determined by

[equilibrium](#) for Storage Ring  
[electron gun](#) for ERL.

Thus

### 1、 energy recovery

Super conducting cavity is essential for energy recovery and continuous operation.

### 2、 electron gun

Development of high quality electron gun is essential!



## What's difference between ERL and FEL?

FEL and ERL are not same!

But both of two already existing ERL machines are used for FEL driver. (J-Lab, JAERI)

### 1、 frequency

FEL 10Hz, 1kHz, 10kHz...

ERL 1.3GHz...

(SR ring: 1MHz, injector LINAC: 50Hz)

### 2、 bunch charge

FEL 1nC, 10nC...

ERL 77pC, 154pC...

(SR ring: 1nC, injector LINAC: 1nC)

### 3、 bunch length (pulse width)

FEL 100fSec, 10fSec...

ERL 10pSec, 1pSec...

(SR ring: 30pSec, injector LINAC: 10pSec)