

Two-frequency RF system for long / short bunches for SPring-8 II

- SPring-8 II
- Higher Harmonic Cavity
- Longitudinal Stability
- Short Bunch Option

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(JASRI / SPring-8)

introduction

- Diffraction Limited Light Source @ 10 keV
 - 10 pm order emittance for SPring-8 II
- Emittance growth / lifetime decrease due to intra-beam scattering
- Harmonic cavity for
 - long bunch with small emittance

Oct.30 Session1 : Lattice design for SPring-8 II

Oct.30 Session4 : High Gradient Magnet Design

Oct.31 Session4 : Injection scheme for the SPring-8 upgrade

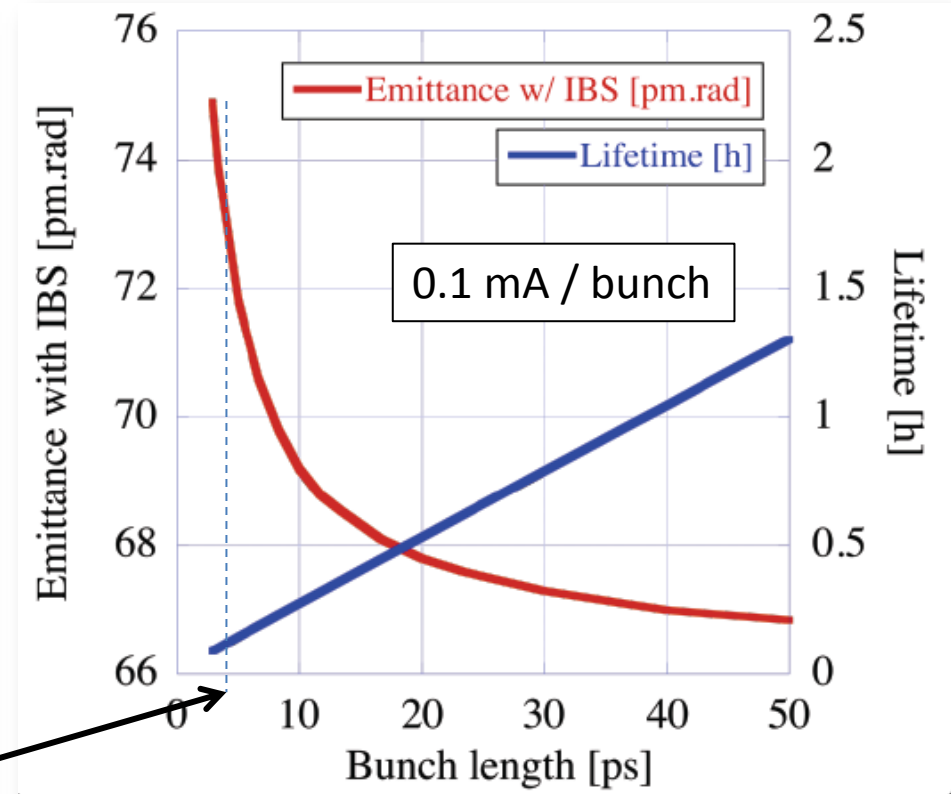
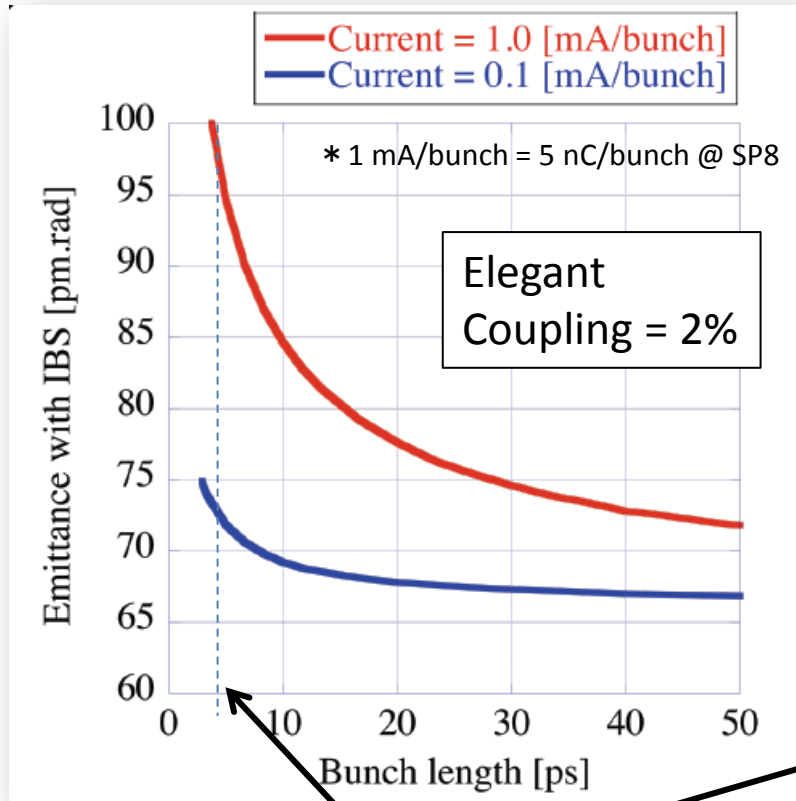
Nov.01 session1 : Multi-Bunch Feedback System in USR

Parameter list of SPring-8 II (tentative)

	SPring-8	SPring-8 II
Beam energy (GeV)	8	6
Beam current (mA)	100	300
Momentum compaction	1.68E-4	1.55E-5
Circumference (m)	1436	1436
RF frequency (MHz)	508.58	508.58
Radiation loss (MeV/turn)	9	4
Harmonic number	2436	2436
Energy spread	0.1%	0.1%
Natural emittance (zero current limit)	3400 pm rad	67.5 pm rad
natural bunch length (zero current limit)	13 ps	5 ps

Emittance growth / lifetime decrease due to intra-beam scattering

T. Watanabe



Zero current bunch length

Lifetime @ 0.1 mA / bunch

0.5 h at 20 ps

1 h at 40 ps

1 mA / bunch : Even at 50 ps, ϵ 10 % grow.

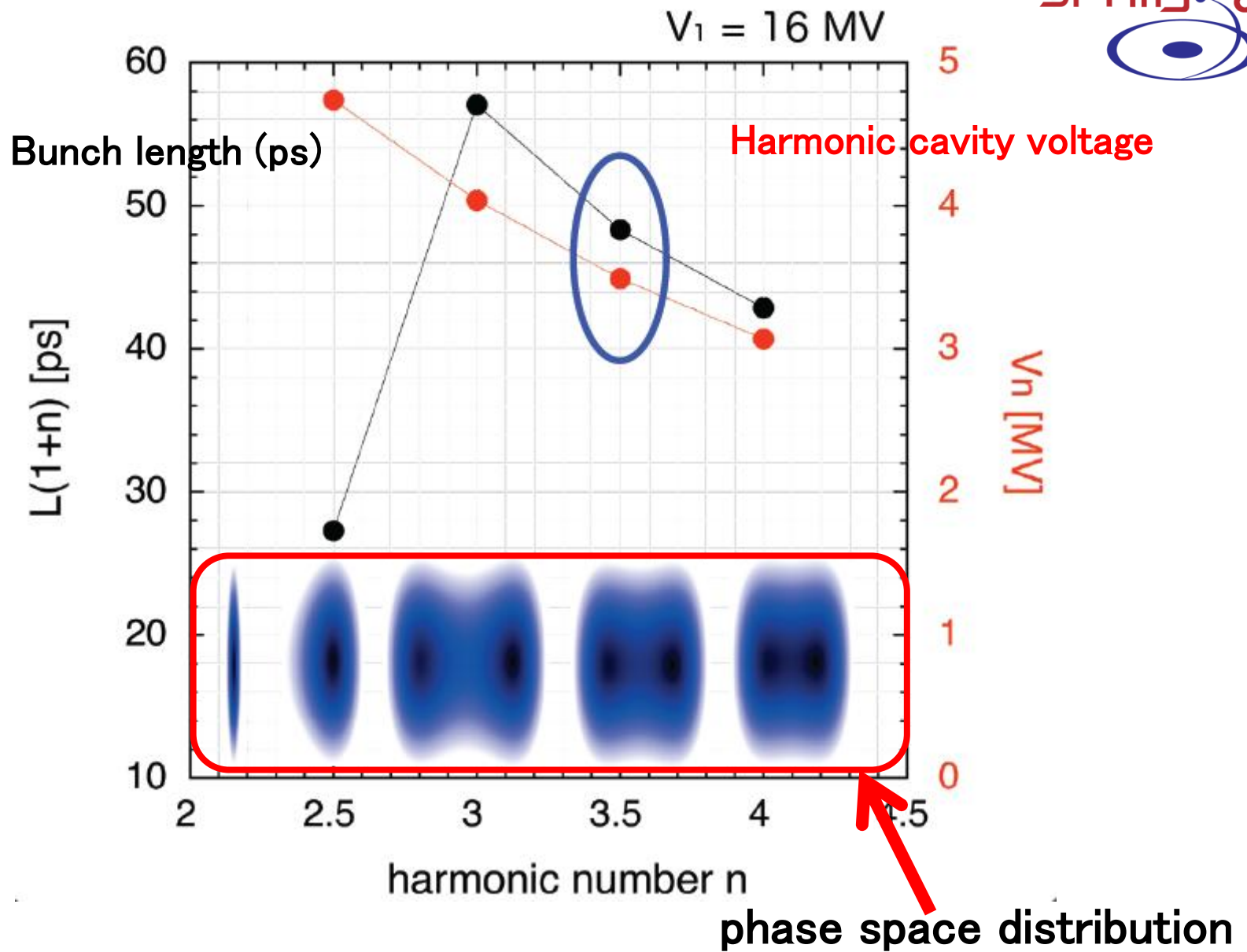
0.1 mA / bunch : More than 20 ps, no growth.

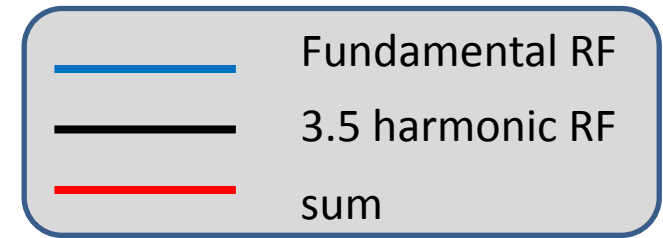
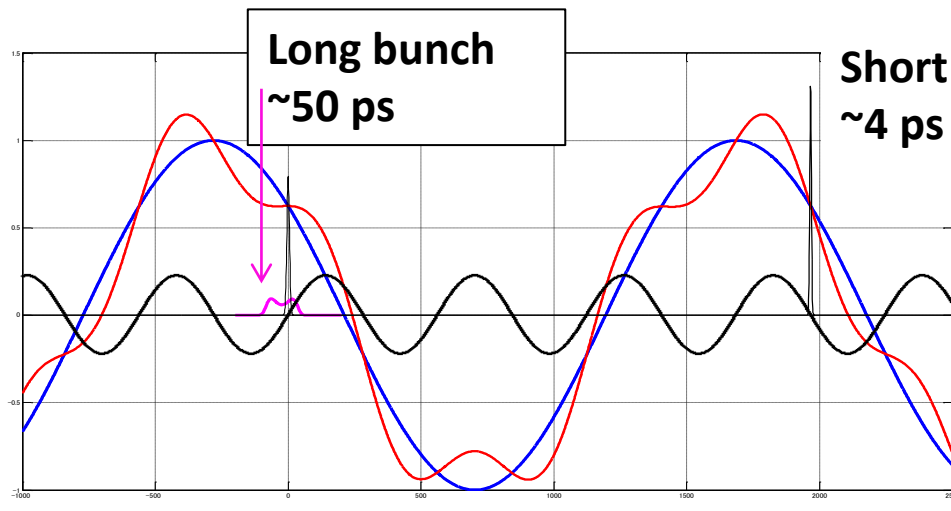


Bunch length:

At least 20ps

Gaol 40~50ps

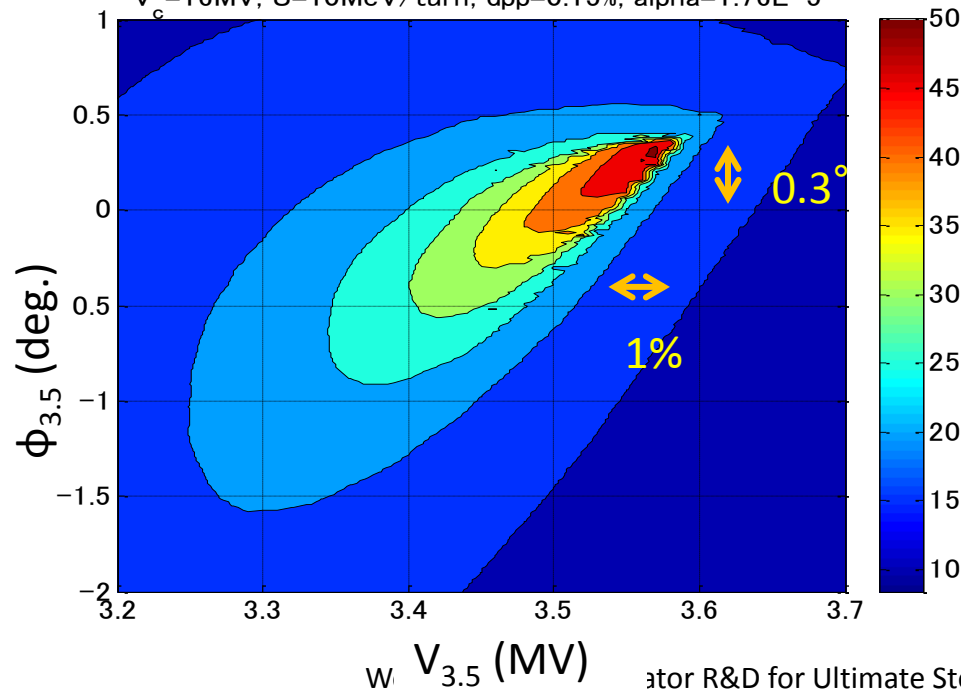




$$V = V_1 \cos(\omega\tau + \phi_s) + V_{3.5} \sin(3.5\omega\tau + \phi_{3.5})$$

bunch length (FWHM/2.35) [ps] scan

$V_c = 16\text{MV}$, $U = 10\text{MeV/turn}$, $dpp = 0.15\%$, $\alpha = 1.76\text{E-}5$



$$\tan \psi_{3.5} = -\frac{2Q_0}{1 + \beta_{3.5}} \frac{nf_{\text{rev}} - f_R}{f_R}$$

$$V_{3.5} = \frac{I_b R_{3.5}}{1 + \beta_{3.5}} F \cos \psi_{3.5}$$

1% voltage stability
0.3° phase stability

Need high precision phase/voltage control system.

- Coupler
- Tuner
- LLRF

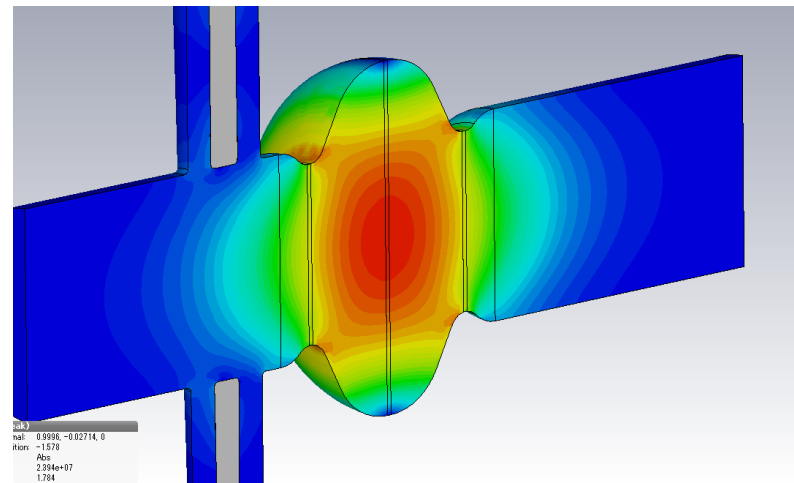
Parameters of the harmonic cavity

f (MHz)	1780.03
harmonic	3.5
mode	TM010
Number of cavity	3 (single cell)
coupling	500-5000
Cavity voltage	1.2 MV
Reflection power (total)	250kW @300mA
Coupler	coax. double-feed
Coupler power	42 kW/each
Operating temperature	2 K
RF generator	10 kW/cavity
Eacc	21 MV/m

- Low R/Q for beam loading
- Superconducting cavity
- Cavity voltage / phase control
 - Coupler / tuner

3.5 harmonic of
500/352MHz is
1750/1232MHz

No SC cavity



Longitudinal Stability(1)

- **Transient beam loading accompanied by bunch gap**

- ELETTRA, PRST-AB 9, 044401 (2006)
- NSLS-II, EPAC08, p. 904

Issue to be solved.

- **Bunch gap is necessary**
for hybrid filling or to avoid ion trapping / fast ion instability.
- **Then, lead RF voltage variation in one-turn.**
- **And results in bunch length variation in one-turn.**



Under study SP8 II case...

Longitudinal Stability(2)

- Robinson instability with Harmonic Cavity has been studied.

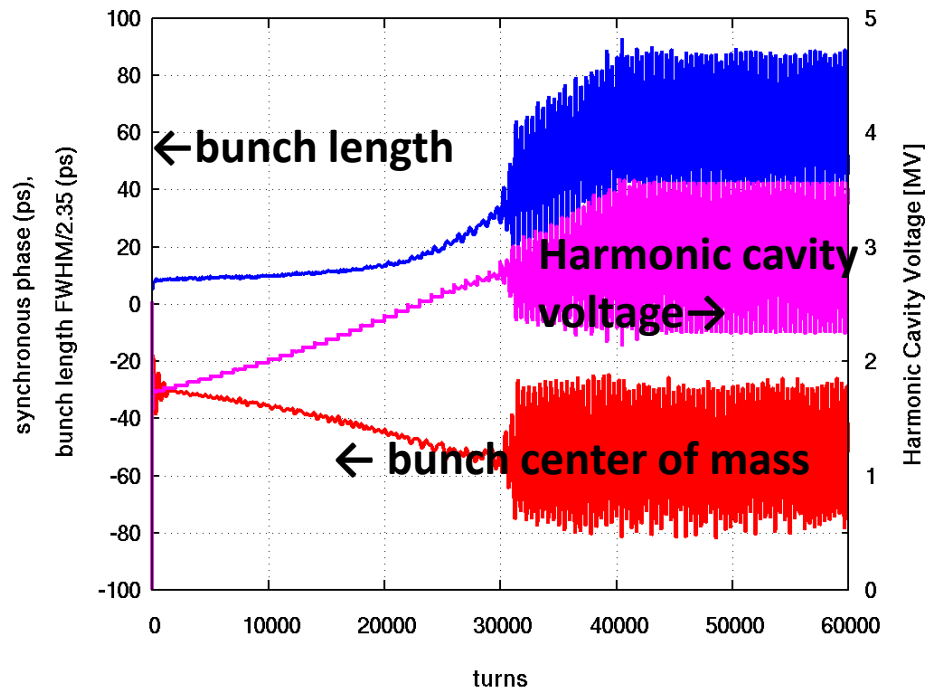
- PRST-AB, Bosch, 4, 074401(2001)



How about 3.5 harmonic case?

Tracking simulation

w. fundamental / harmonic cavity impedance
w.o. broad-band impedance



Synchrotron oscillation feedback

- Synchrotron frequency fluctuate depending on the harmonic voltage and phase.

Detect and feedback $\Delta p/p$ directly

Bunch center of mass and bunch length oscillation was successfully suppressed by weak feedback gain.

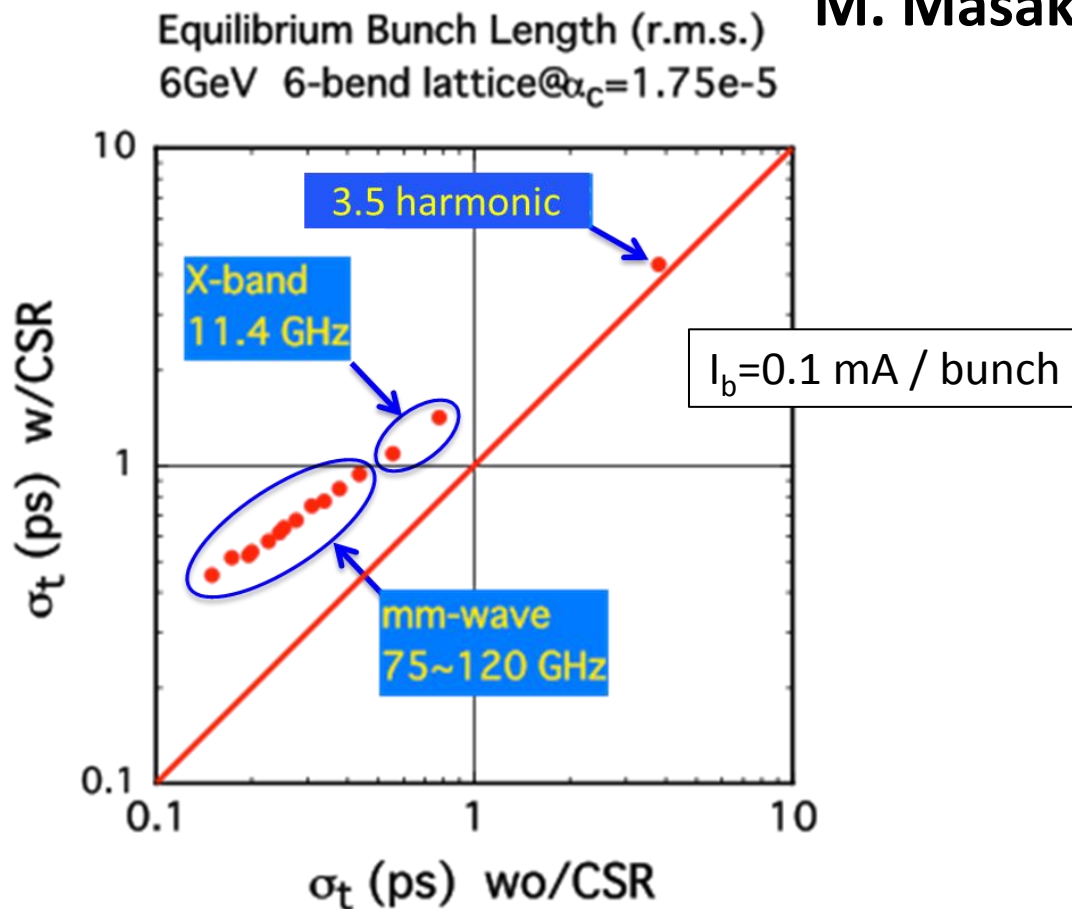
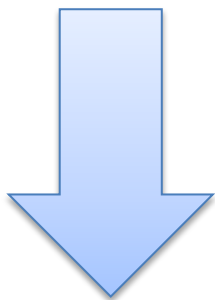
Bunch center of mass and bunch length oscillate above 2.7MV. Not exponential growth.

Short bunch option

- As an option of SPring-8 II, short bunch scheme is under study.
- At SPring-8 site, SACLA(XFEL) provides **a few 10 fs** X-ray, SPring-8 II : **20 ps~50 ps** and **4ps**.
 - X-ray of **sub ps range** is a gap.
- Concept : Provide sub-ps X-ray to **all Beamlines**
- How to achieve sub-ps bunch?

CSR effect

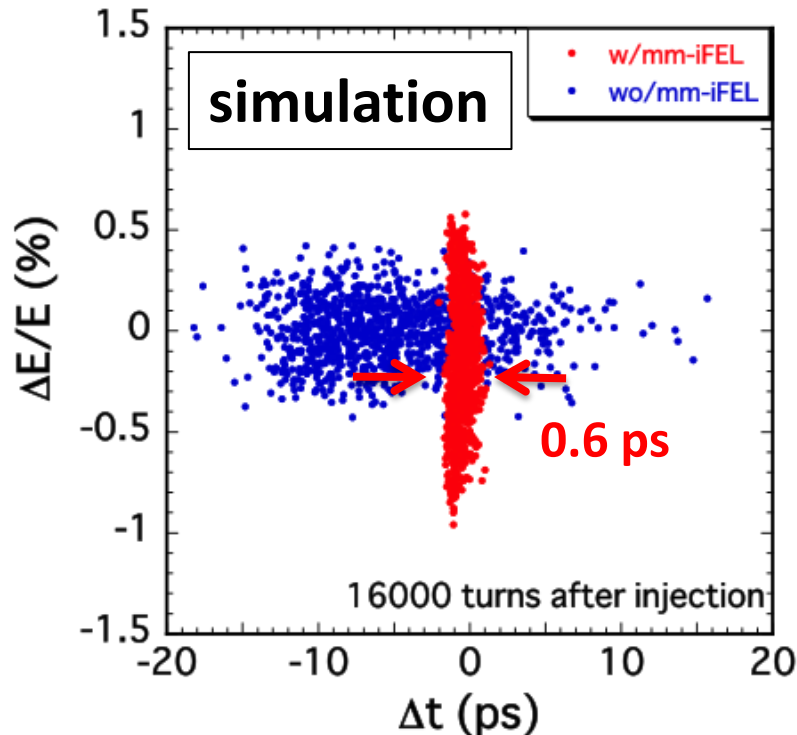
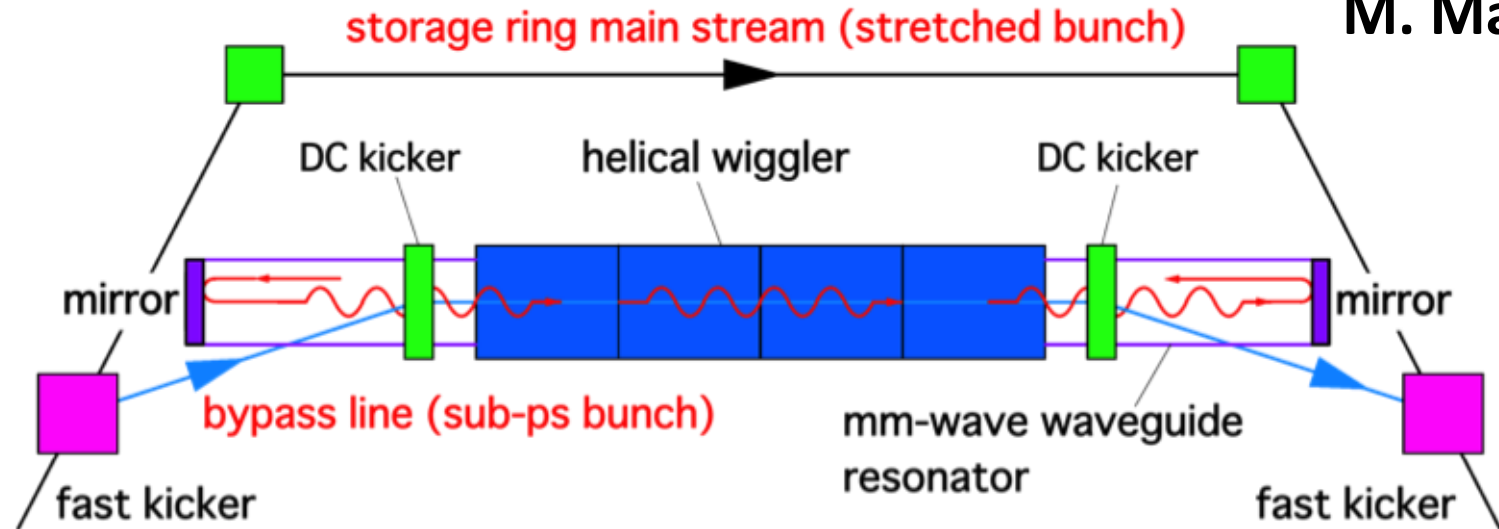
Influence of CSR effect becomes significant at sub-ps – 1ps bunch length.



- mm-Wave is required to achieve the equilibrium bunch length less than 1 ps.

Sub-ps Short Bunch Generation by mm-Wave Inverse FEL

M. Masaki



mm-Wave Corrugated Waveguide

Propagation Mode : HE11

Frequency : 165.5 GHz

Guide Wavelength : 3.06 mm

IPAC11 M. Masaki et al., THPC028

When the mm-wave Peak power of 1.8 GW is accumulated in the resonator



Compressed Bunch of **0.6 ps (r.m.s.)**,
but Energy Spread broadened \rightarrow 0.3 % (r.m.s.)

summary

- Two-frequency RF system (main RF+3.5 harmonic) is planned for SPring-8 II.
 - Ultra-low emittance for long bunch (~40ps)
 - Short bunch (~4ps w/ CSR w/o wake)
- Bunch gap effect on bunch length is under study.
- Possibility of longitudinal instability (tracking)
- Direct feedback of dp/p with small gain would suppress the instability.
- Sub-ps bunch option by a mm-wave iFEL scheme is under study.

Synhrotron tune spread

