Multi-bunch feedback system for USR

- BBF (bunch-by-bunch feedback) system
- Ultra-low emittance ring for Light source
- Narrow gap undulator / narrow beam pipe
- BBF for Hybrid filling
- Effect of noise on beam size
- High resolution BPM
- Number of bit

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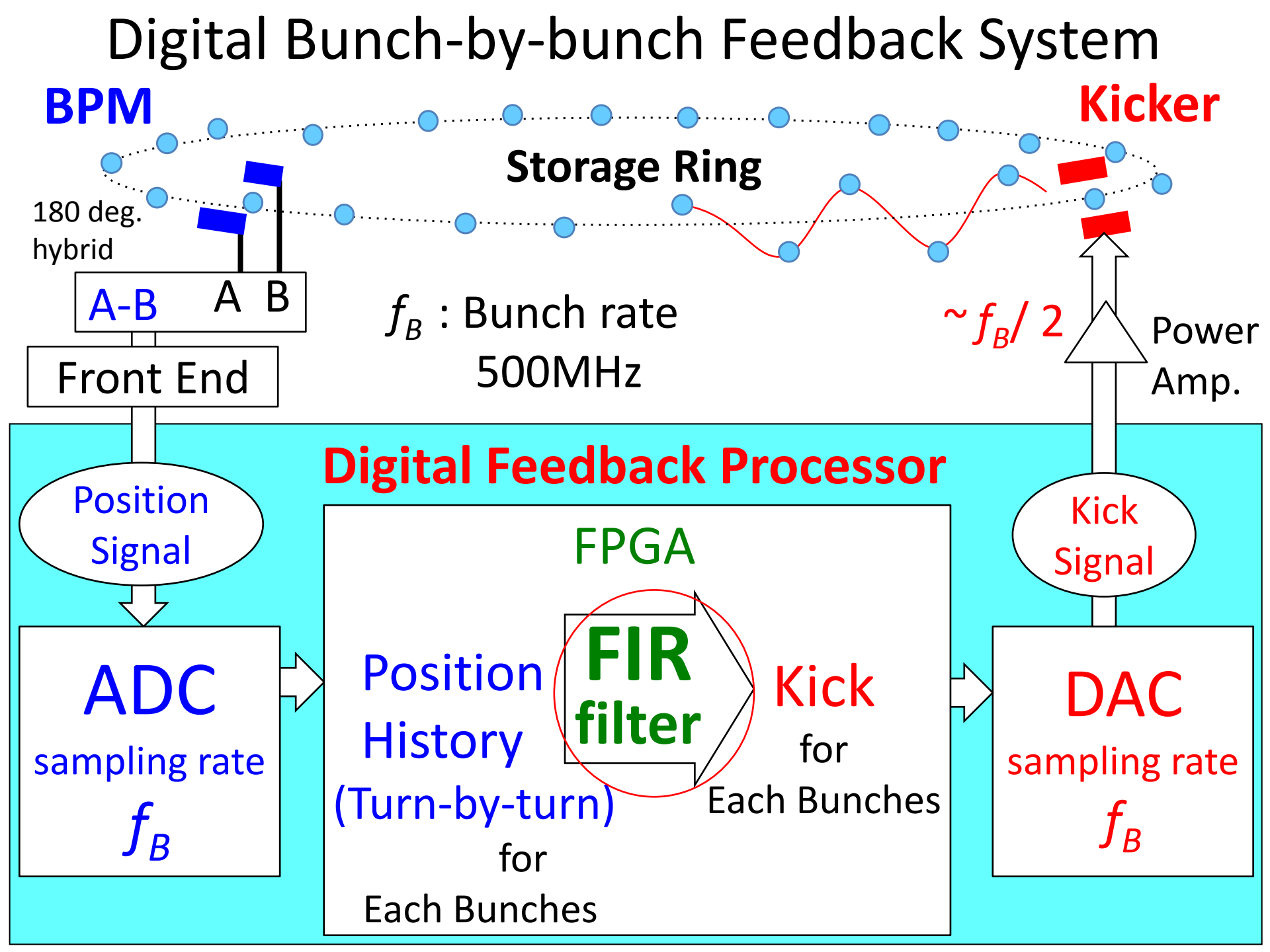
(JASRI / SPring-8)


Digital Bunch-by-bunch Feedback System
BPM
Kicker
Storage Ring
180 deg.
hybrid
A-B
A
B
Front End
f_B : Bunch rate
500MHz
~ f_B/ 2
Power
Amp.
Digital Feedback Processor
Position
Signal
Kick
Signal
FPGA
ADC
sampling rate
f_B
Position
History
(Turn-by-turn)
for
Each Bunches
FIR
filter
Kick
for
Each Bunches
DAC
sampling rate
f_B

Ultra Low Emittance Ring for Light Sources

Hybrid filling

High Bunch Current Singlet Bunches + High Average Current Bunch Trains

Narrow Gap Undulators + Narrow Beam Pipe for Strong Magnets

=> Strong Impedance ~ $1/gap^3$

=> Resistive-wall Multi-bunch Instability

=> Mode-Coupling Single-bunch instability

Multi-bunch Feedback

Horizontal and Vertical Resistive-wall Multi-bunch Instability

Stabilized for > 100mA average current at SPring-8

Transverse Mode-Coupling Single-bunch instability

Threshold bunch current

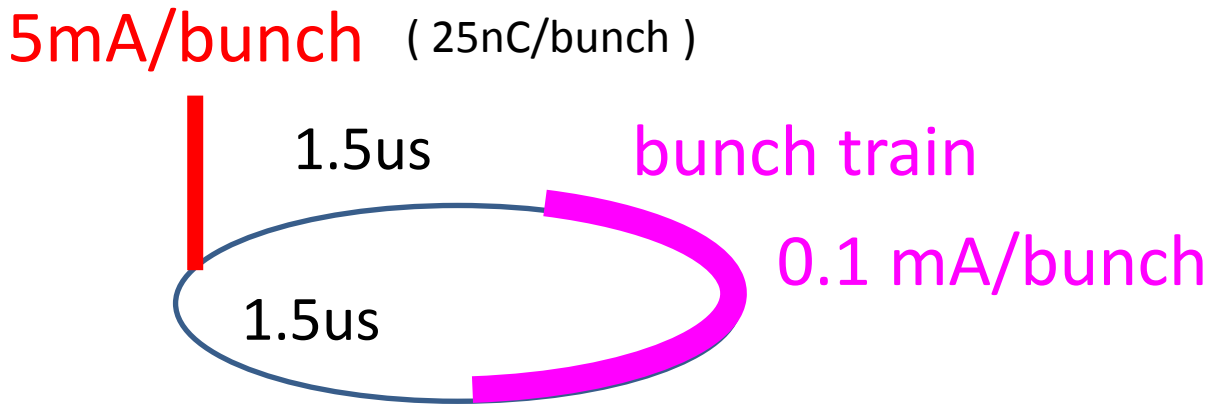
2 mA/bunch => 5mA/bunch at SPring-8

Kick angle by Feedback Kicker ~ Oscillation amplitude / Damping Time

(excited by Injection perturbation)

=> Strong Horizontal Kicker

Light Sources : Hybrid Filling with High Bunch Current Singlet



High Bunch Current

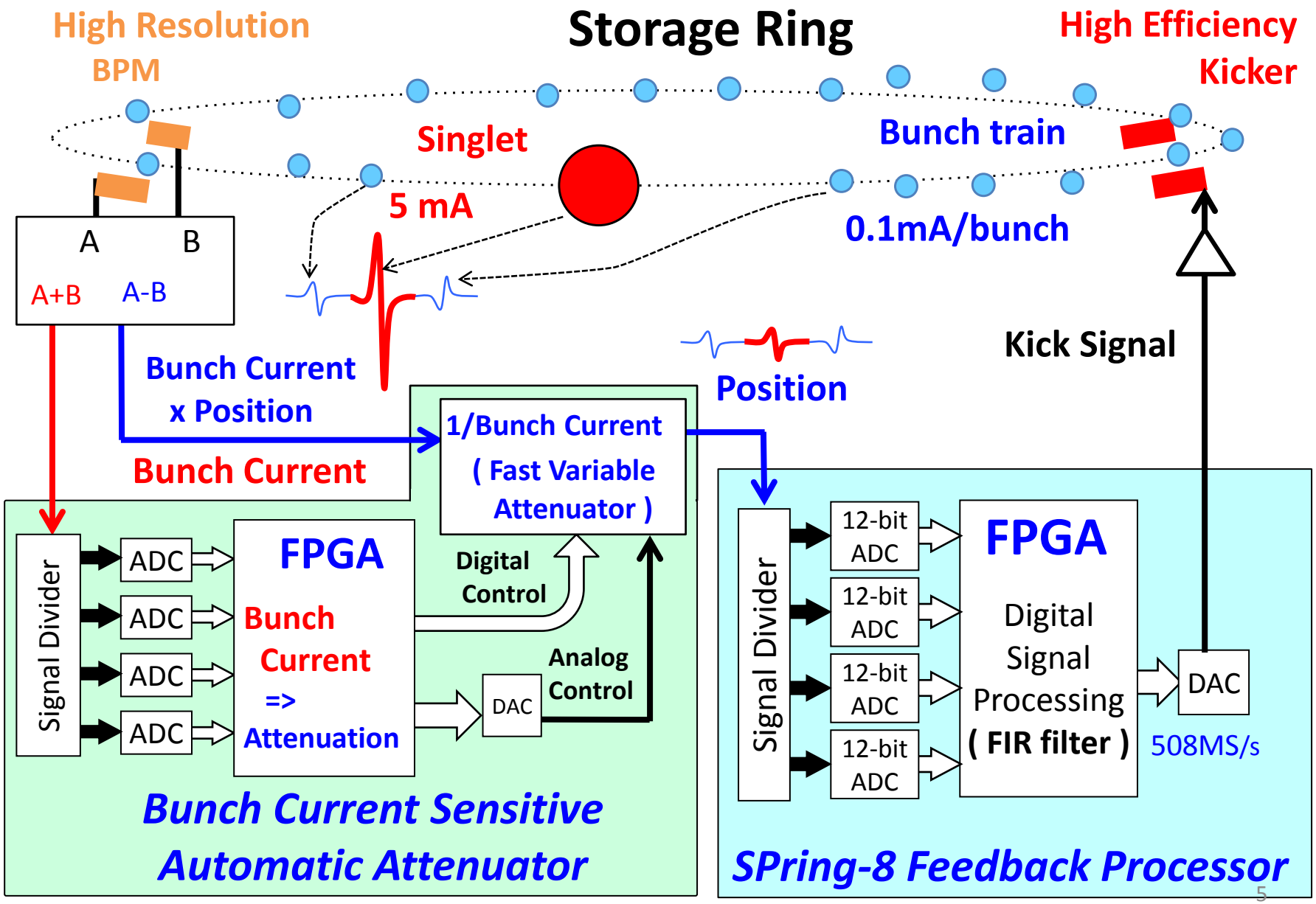
Bunch Train
Low bunch current but
High Average Current

Single-bunch Instabilities
(mode-coupling instability, ..)

Multi-bunch Instabilities
(Resistive-wall, ..)

Multi-bunch Feedback : Simultaneously suppressed
with Difference of **Two order Magnitude of bunch current**

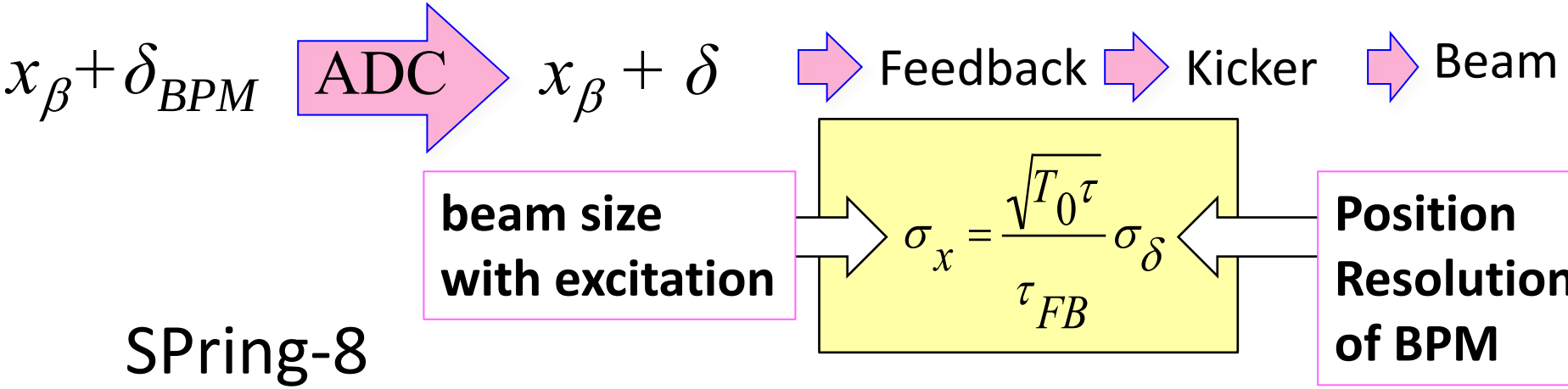
Multi-bunch Feedback with Automatic Attenuator



Effect of Noise

Residual Oscillation Excited by Noise

Residual oscillation for Position Measured with Noise δ



SPring-8

Revolution Freq.	T_0	**~5 μs**
Total Damping Time	$\tau \sim \tau_{FB}$	**0. 5 ms**

$$\sigma_x = 0.1\sigma_\delta$$

Allowable Amplitude σ_x **< 0.5 μm (~ 0.1 x Beam Size 5 μm)**

Position Resolution $\sigma_\delta = 10\sigma_x <$ **5 μm for 0.2 nC/bunch**

With High resolution BPM

T. Nakamura, et al., EPAC'04, http://accelconf.web.cern.ch/AccelConf/e04/PAPERS/THPLT068.pdf
T. Nakamura, NanoBeam '05, http://atfweb.kek.jp/nanobeam/files/proceeding/proc-WG3b-12.pdf
http://beam.spring8.or.jp/nakamura/papers/Nanobeam05/proc-WG3b-12.pdf

Residual Oscillation Excited by Noise

Revolution Freq. $T_0 = 5\ \mu s$ (C = 1500m)

Feedback Damping Time $\tau \sim \tau_{FB} = \underline{\mathbf{0.05\ ms}}$

½ gap -> 10 times faster growth rate

$$\sigma_x = \frac{\sqrt{T_0 \tau}}{\tau_{FB}} \sigma_\delta \sim 0.3\ \sigma_\delta$$

Beam size $\sigma_V \sim 3\ \mu m \quad (\beta_V = 5m,\ \varepsilon_V \sim 2\ pm)$

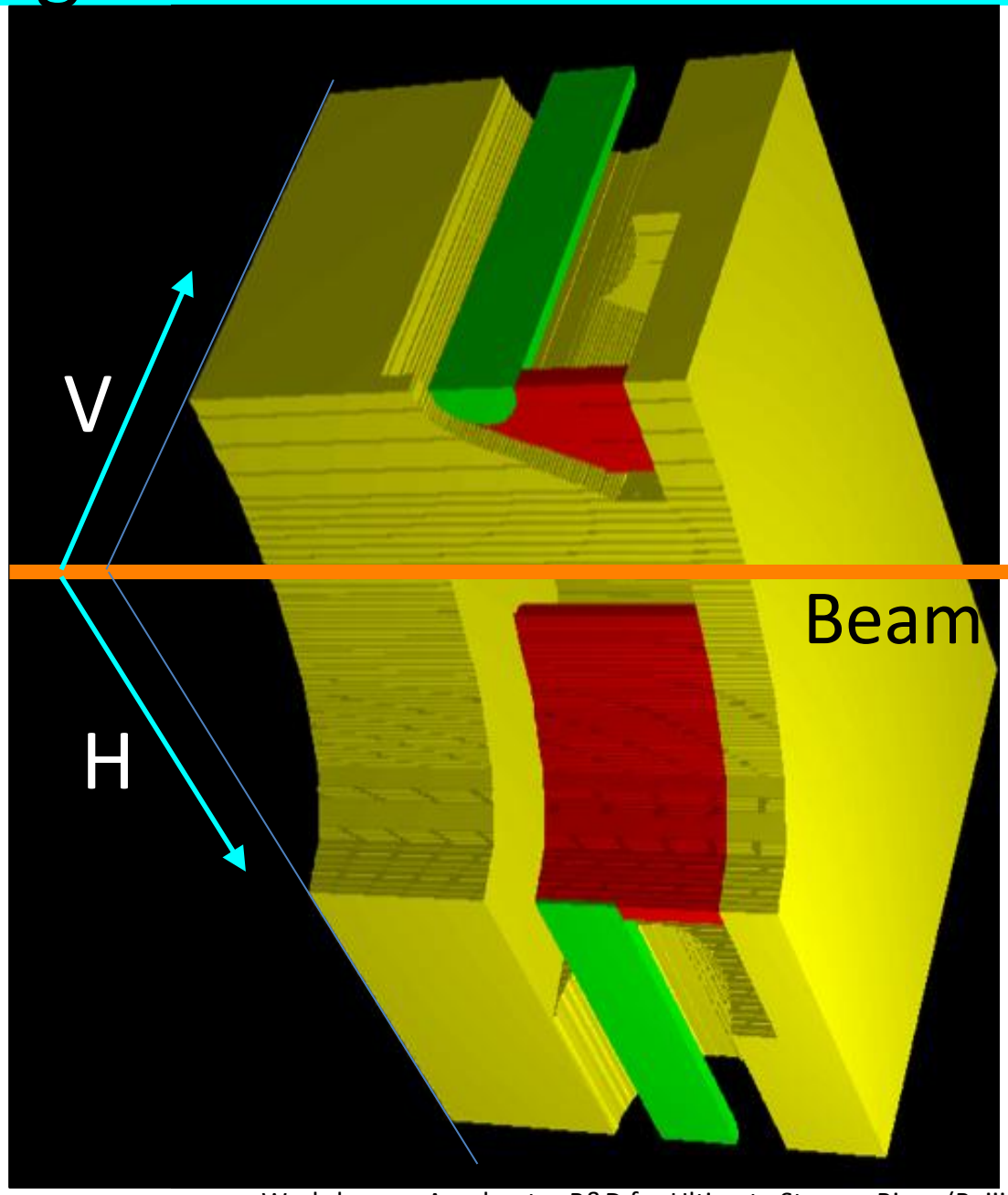
Allowable Amplitude $\sigma_x < 0.3\ \mu m$ ~ 0.1 x Beam Size

Position Resolution $\sigma_\delta < 1\mu m$ for 0.6nC bunch

(300mA, 2ns spacing)

for BPM at $\beta_V = 5m$ (larger β_V is better)

High resolution Beam Position Monitor



$\sigma_V = 5\mu m$

for 0.2nC bunch
(=100mA x 2ns)
@40mm aperture

$\sigma_V = 0.4\mu m$

for 0.6nC bunch
(=300mA x 2ns)
@20mm aperture

ADC resolution (How many bits ?)

Step size << Beam size 3um (USR), 5um (SP8)

Acceptance < Maximum Amplitude 0.2 – 0.3 mm

for SPring-8 by Injection perturbation

⇩

Step size = 0.25 um

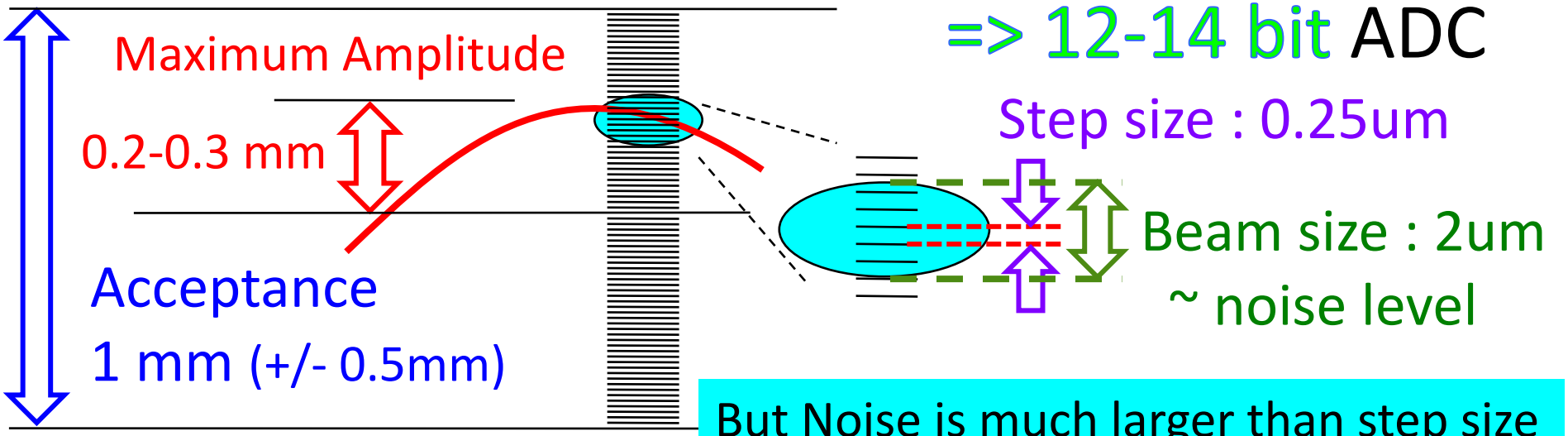
Acceptance = 1mm (+/- 0.5mm)

for SPring-8

Number of Step = Acceptance / Step Size

= 1mm / 0.25um = 4000 = 12bits

=> 12-14 bit ADC



But Noise is much larger than step size

summary

- Ultra-low emittance ring for Light source
  - Hybrid filling
  - Narrow gap undulator / narrow beam pipe

  ⇒ Bunch-Current Sensitive Attenuator
- Effect of noise on beam size is discussed.

  ⇒High resolution BPM with narrow beam pipe is enough for 3um beam-size ring.
- 12-bit ADC is required.

Thank you for your attention!