Multibunch beam stability in damping ring (Proposal of multibunch operation week in October)

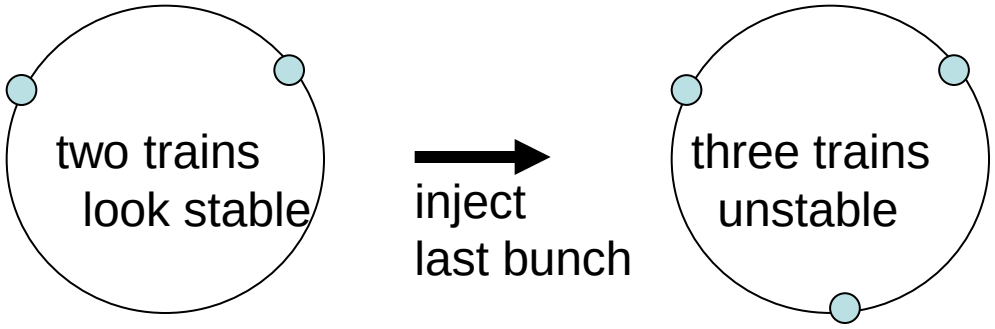
2010. 07.02 K. Kubo

Need stable multibunch beam for

- ATF2, Final Focus demonstration
  - especially the goal 2, beam position stability < 2 nm at “IP”. (this is 5% of beam size)
- FONT, bunch by bunch feedback demonstration
- Fast ion instability studies
- , , , , ,

Unstable multibunch beam -1

- In 3 train operation (1 bunch/train)
  - Vertical oscillation (horizontal and/or longitudinal too?)
  - Vertical beam size blowup by X-ray profile monitor (20 ms gate)
  - Bunch to bunch (uncorrelated) jitter observed in FONT study
  - Sometimes stable. (May depend on chromaticity ???)
  - Insensitive to slight change of tunes (?)
  - No clear explanation



Unstable multibunch beam -2

- Multibunch/train operation
  - Longitudinal oscillation in tail bunches
    - Amplitude depend on intensity
    - Observed by streak camera
  - Vertical motion was stable at low intensity in past studies.
    - Beam size measured by DR Laser Wire
    - For high intensity, unstable, which we suspected to be fast ion instability

- According to simulations, Cavity wakefield should not cause coupled bunch instabilities.
- **It is difficult to explain. Need more experimental information**

Studies for multibunch - 1

Survey parameters

- Bunch fill pattern: number of bunches, number of trains
- Bunch intensity
- Tune and chromaticity
- Orbit
- RF voltage
- RF frequency
- Parameters of RF feedback

Some of past observations look inconsistent each others.
More systematic study will be necessary.

Studies for multibunch - 2

Measure oscillations in detail

- Frequencies of oscillation, by spectrum analyzer
  - It looks easy, if the oscillation is from a narrow resonance (?)
- Turn-by-turn BPM
  - We can measure TBT of one selected bunch (T.Naito)
  - FONT group can provide BBB TBT position (P.Burrows) Need some works.

Some more simulations, if necessary.

Other thing to be done for stable beam in EXT

- Check effectiveness of feed-forward using FONT like system
  - Measure correlation between DR (last turn) and EXT orbits (Need some work for synchronize monitors in DR and EXT.)

Multibunch injection

Need high current injection tuning

- Recently, only N~0.1E10/bunch can be injected and stored in DR
- Establishing tuning procedure is important too

Why multibunch injection is difficult?

- Possible bunch to bunch energy difference.
- Effects of transient beam loading of RF cavities
  - During injection, transient beam loading causes synchrotron oscillation and reduce energy acceptance.
- Effects of transient transverse wakefield of RF cavities
  - Reduce transverse orbit error acceptance

Proposal of “multibunch operation week”

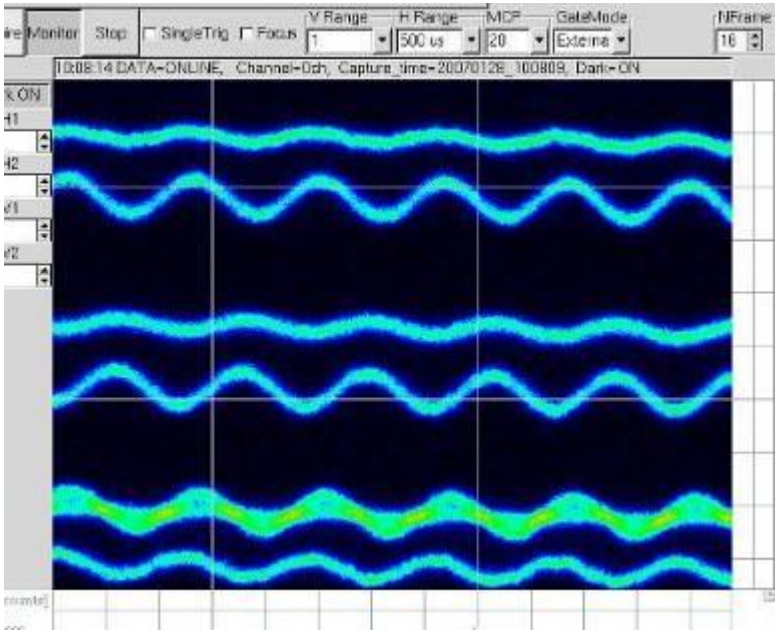
- In October 2010, one week dedicated to multibunch studies
  - Perform experimental studies listed in previous slides
    - Probably, about 16 hours/day, 4 days (depends on manpower)
  - Probably week of Oct. 25.
- Need more detailed plans.
  - Have meeting of a small group

Summary

- Multibunch instabilities have been observed
  - 3 train (single bunch/train) and multibunch (single train)
  - Need systematic studies
    - Survey parameters
    - Measure oscillation in detail (with BBB TBT BPMs)
- Injection tuning also needs to be studied.
- Dedicated 1 week of multibunch operation is proposed.

Buck up slides

Longitudinal oscillation in tail bunches



Streak camera,
Multi bunch single train
Horizontal axis: long range time
Vertical: short range time
Each line is from one bunch.
(Should be flat for stable bunch)

Tail bunches oscillate larger than head bunches.

[by Naito]

Each line shows on bunch in a train, not in order.

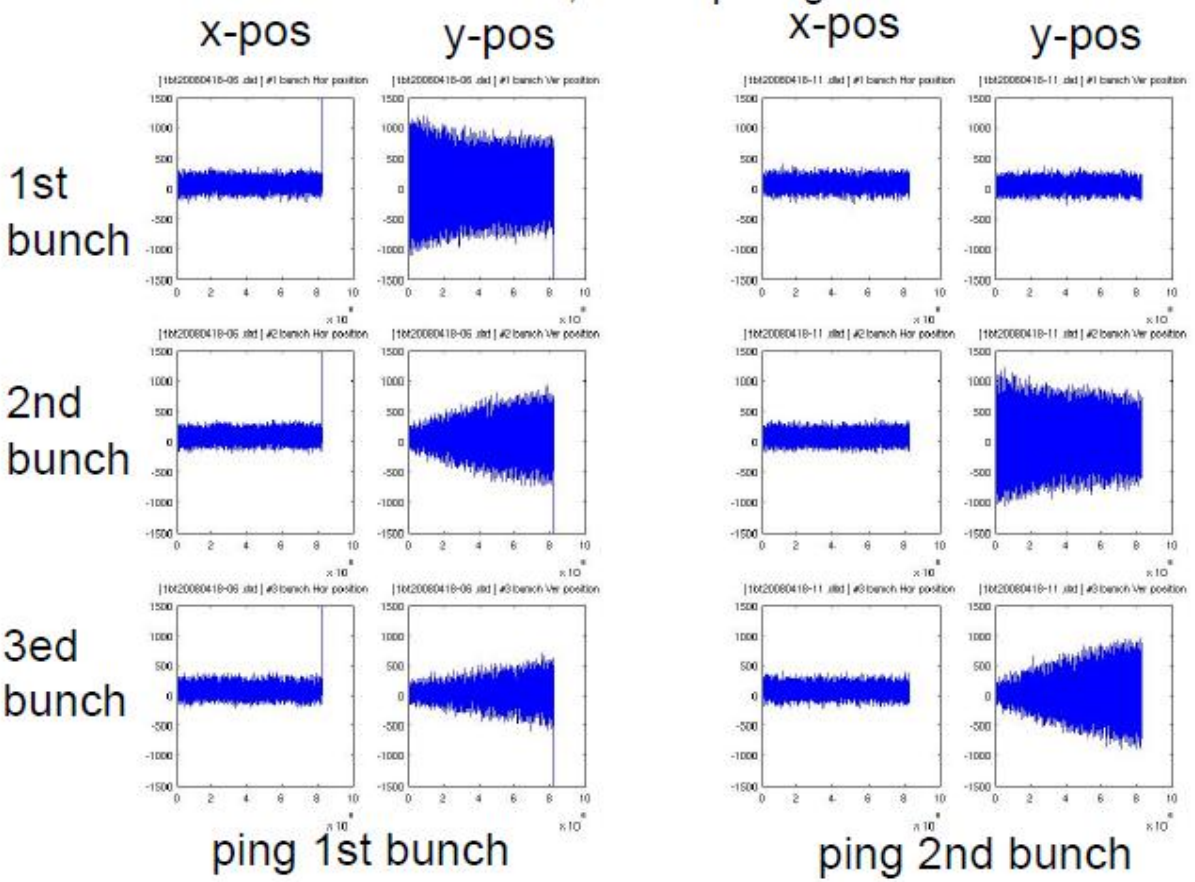
Transient transverse oscillation growth

Can be explained by cavity wakefield

Effectively increase damping time, but should be damped at last.

Multi-bunch oscillation monitor by Naito

3 bunches, 2.8ns spacing



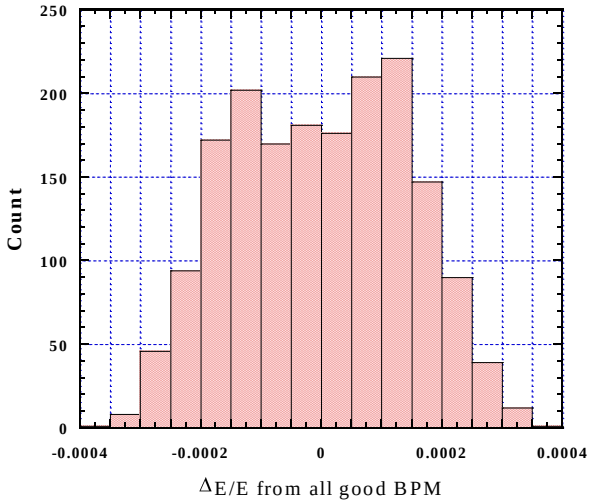
Single bunch - measured longitudinal jitter

Energy: $\Delta E = \Delta x / \eta$ at any location in DR
Use as many BPMs
Energy deviation is expressed as

$$\Delta E = \sum_{\mathrm{BPM}} \Delta x \, \eta_x \Big/ \sum_{\mathrm{BPM}} \eta_x^2 , \quad (\Delta x = x - x_{\mathrm{mean}} \ \text{for each BPM})$$

assuming all BPM have the same resolution.

The shape (Non-Gaussian) of distribution suggests synchrotron oscillation.
RMS is about 1.4E-4.
(Natural energy spread ~ 5E-4)



Single bunch - measured transverse jitter

Fit ***a*** and ***b*** for each pulse, using measured position at i-th BPM as

$$x_i = a\beta_{xi}\cos\phi_{xi} + b\beta_{xi}\sin\phi_{xi}$$

x_i : measured position (subtracted by $\Delta E\,\eta_{xi}$),

β_{xi} : betafunction, ϕ_{xi} : betatron phase

East arc and west arc, separately

	east+west	east-west	**correlated**	uncorrelated
x cos-like (*a*)	6.114e-6,	3.130e-6	**2.62e-6**	1.57e-6
x sin-like (*b*)	5.976e-6	3.739e-6	**2.33e-6**	1.87e-6
y cos-like (*a*)	6.244e-6	5.942e-6	**0.96e-6**	2.97e-6
y sin-like (*b*)	3.305e-6	3.982e-6	**Imaginary**	1.99e-6

Correlated: Real betatron oscillation

Uncorrelated: Noise (limit of measurement)

→Horizontal oscillation: 0.1 σ_x (if emittance = 1 nm)

→Vertical oscillation: < 0.5 σ_y (if emittance = 4 pm)