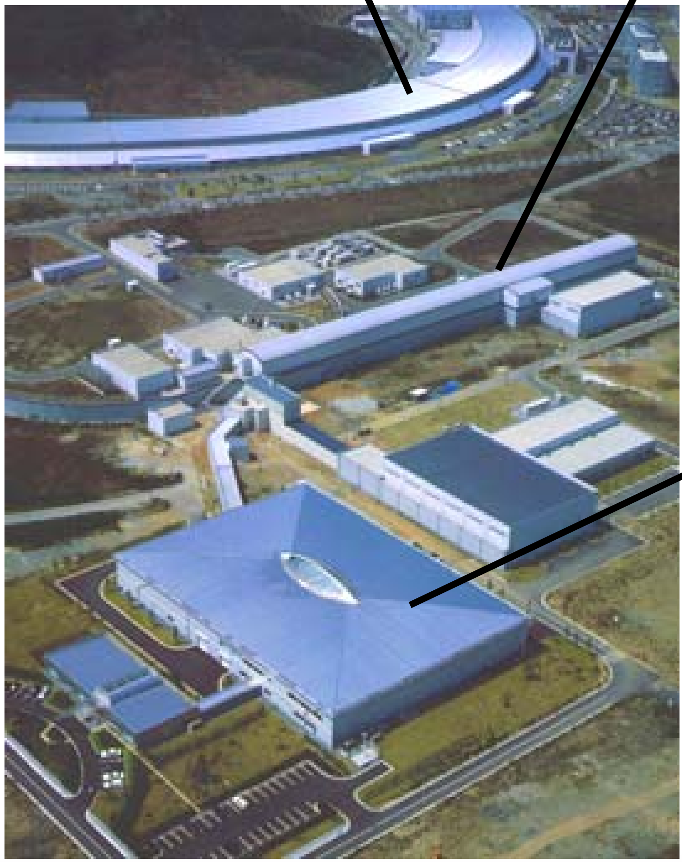
Coherent THz radiation at NewSUBARU

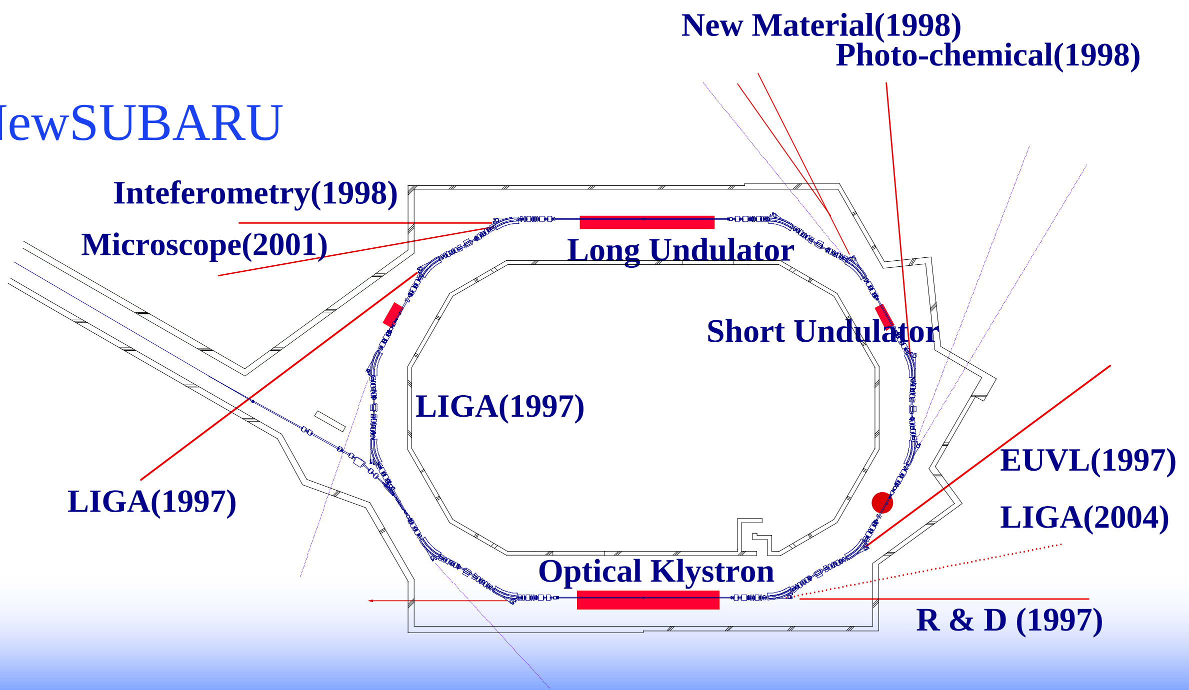
Y. Shoji

NewSUBARU,
LASTI,
University of Hyogo

Introduction to NewSUBARU



Circumference	118.7 m
Injection Energy	1.0 GeV
Electron Energy	0.5 - 1.5 GeV
Type of Bending cell	DBA with Inv.B
RF Frequency	499.956 MHz
Natural Emittance	38 nm (1GeV)
Natural Energy Spread	0.047% (1GeV)



Special design: Invert Bend

Momentum compaction factor

$$\Delta L/L_0 \equiv \alpha_1\delta + \alpha_2\delta^2 + \alpha_3\delta^3 + \ldots.$$

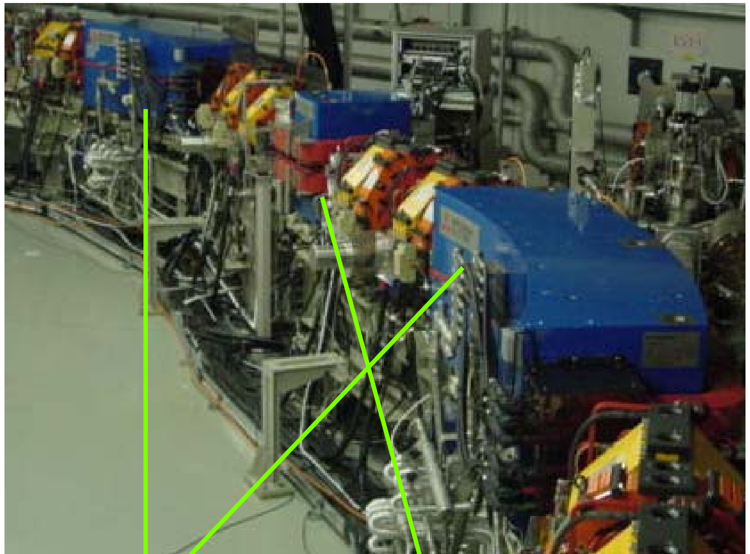
$$\delta \equiv (E - E_0)/E_0$$

Change η in the invert bends

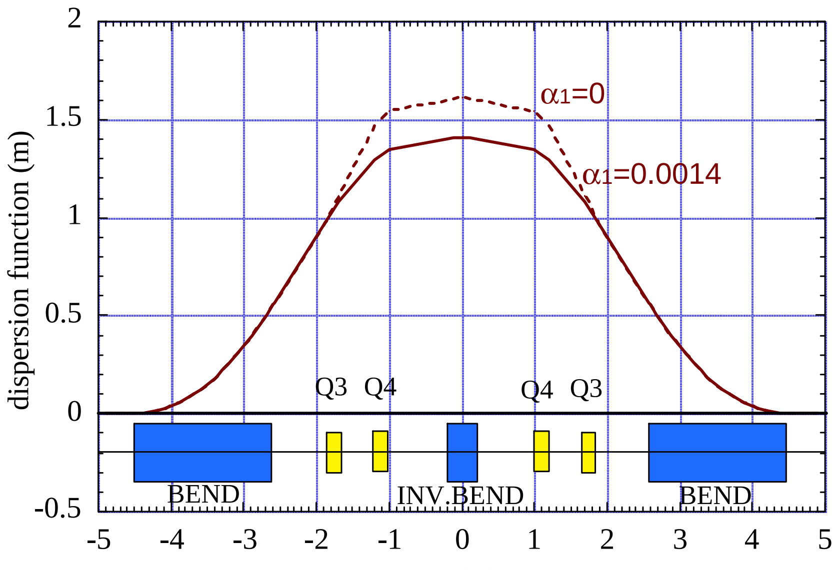
--> change α_1

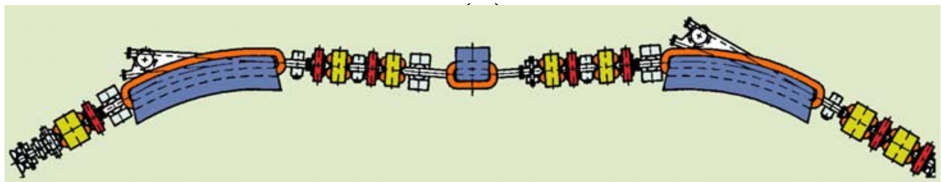
keeping achromatic condition

$34^o\ -8^o\ +34^o = 60^o$



Normal Bend   Invert Bend





Control of momentum compaction factor

Momentum compaction factor

$$\Delta L/L_0 \equiv \alpha_1 \delta + \alpha_2 \delta^2 + \alpha_3 \delta^3 + \; . \; . \; . \; .$$

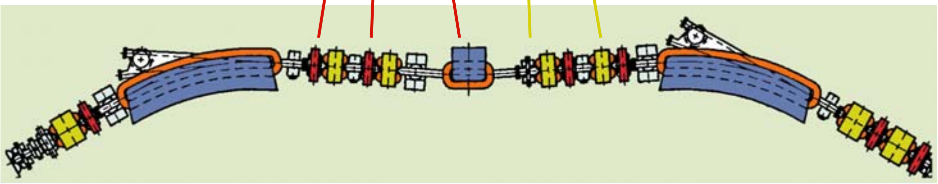
$$\delta \equiv (E - E_0)/E_0$$

$\alpha_1 = 1.3 \times 10^{-3} \rightarrow \approx 0$ Q3 & Q4

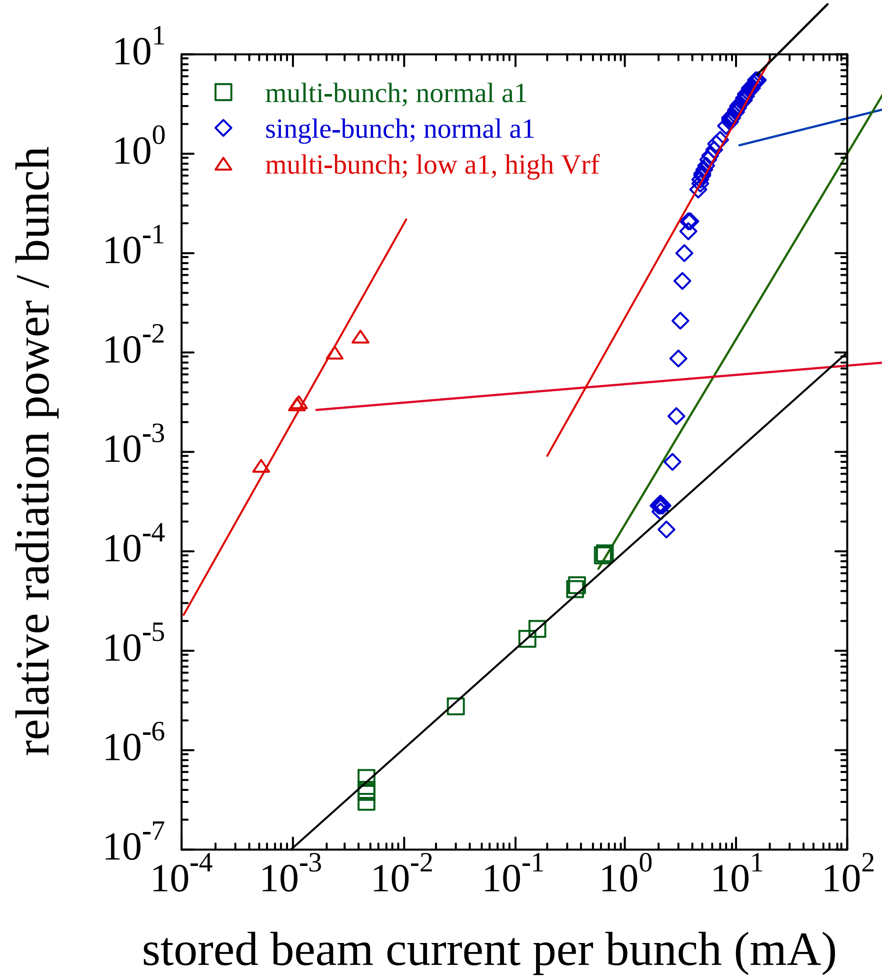
$\alpha_2 = 0$ SF, SD, (SB)

$\alpha_3 \approx 0.5$ no control knob

$\alpha_4 \approx -20$ no control knob



Types of CSR



Normal radiation

CSR burst

normal α_1, high peak current

--> WIRMS2007

Steady state CSR

small α_1 (quasi-isochronous ring)

Beam physics ---> Instability threshold

<u>Acc. technology ---> stability problem</u>

Linac Pulse CSR --> morning session

No laser induced CSR

NewSUBARU has bunch shortening limit

What limit the bunch shortenning?

Bunch shortenning at NewSUBARU

Deviation from the scaling law

$\sigma_T \propto \sqrt{\alpha_1}$ is valid for $\alpha_1 > 2\times10^{-5}$

$\sigma_{T-MIN} \approx 1.4\text{ps}$ at $\alpha_1 \approx 1\times10^{-5}$

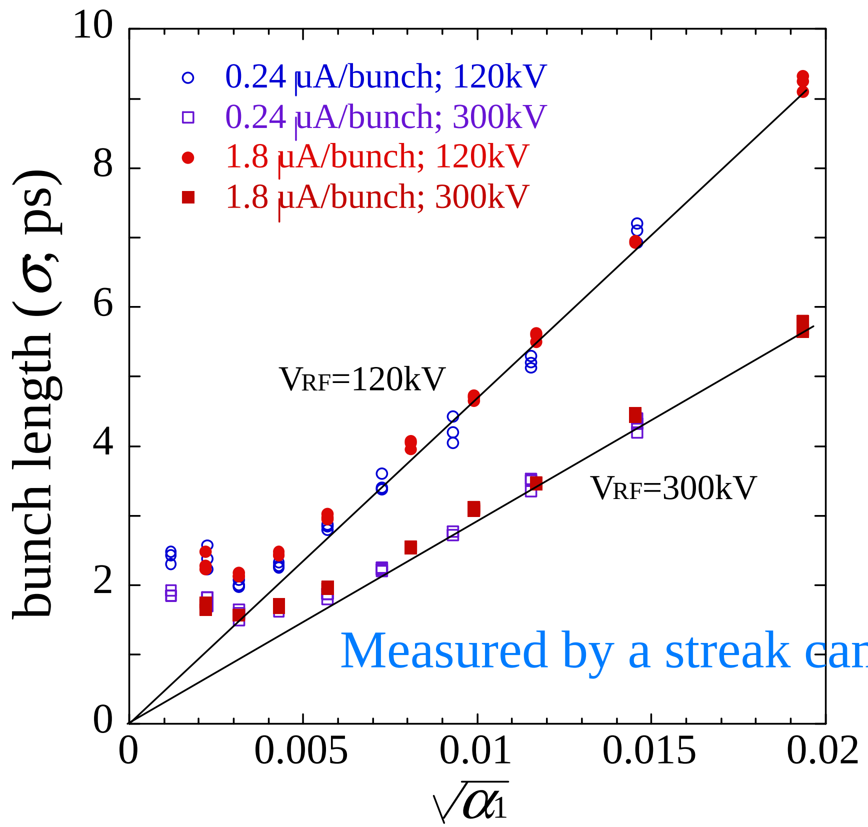
Instability ? No

no I_B dependence at I_B<2μA

Problem of monitor ? No

α_1 does not reduce σ_T

V_{RF} does reduce σ_T



Measured by a streak camera

BESSY & ANKA do not have that problem!

Comparison of NewSUBARU with BESSY

	BESSY II	NewSUBARU
Natural Energy Spread	0.08%	0.047%
Natural Emittance (nm rad)	30π	30π
α_1	-1.4×10^{-6}	5×10^{-6}
α_3	-0.01	0.5
Damping time	8ms	12ms
Lattice	non-achromatic DB	DBA+IB

Ripple & stability of magnets

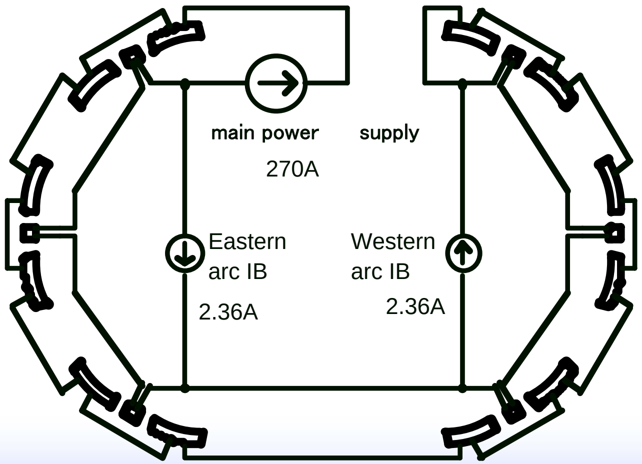
Magnet	Power supply		Effect	
	resolution	ripple	resolution	ripple
B		< 1E-6		$\Delta E/E$= 1E-6
Inv Bend		< 1E-5		$\Delta B/B$= 1E-6 *
Q4	1.5E-5 (16bit)	< 2E-6	$\Delta\alpha_1$= 4E-6*	$\Delta\alpha_1$ = 6E-7
Sext-F	2.4E-4 (12bit)	< 2E-5	$\Delta\alpha_2$ = 2.6E-3 *	$\Delta\alpha_2$ = 2E-4
RF with FB		< 0.02 deg		$\Delta\tau$= 0.1 ps

* Imbalance between B and IB

* α_1=4X10^{-6} --> σ_T=0.6 ps (E_0=1GeV, V_{RF}=300 keV)

* *stability condition;* $\alpha_1 + 2\alpha_2\delta + 3\alpha_3\delta^2 > 0$

—> $\alpha_1 > 4.5 \times 10^{-6}$



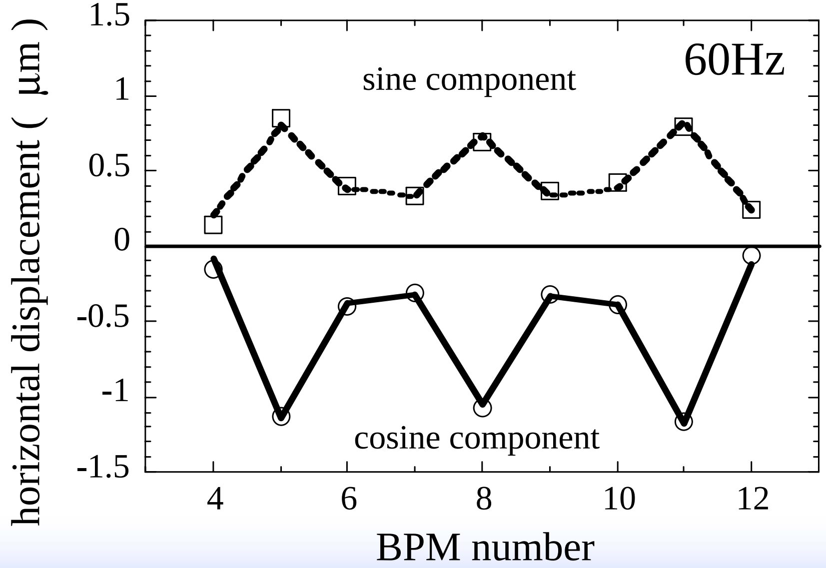
Effect of IB field ripple -- path-length ripple

Dipole field error produces longitudinal oscillation

Deflection θ_S Δx $$\Delta x(s) = \frac{\sqrt{\beta_S \beta(s)}}{2\sin\pi\nu}\theta_S \cos\left[\left|\psi(s)-\psi_S\right|-\pi\nu\right]$$

ΔL $$\Delta L_0 = \int_0^{L_0} \frac{x(s)}{\rho(s)} ds = \eta_S \theta_S$$ --> ΔE $$\frac{\Delta E}{E} = -\frac{\eta_S}{\alpha L_0}\theta_S$$

Evidence of path-length ripple (at normal operation)



COD drift with harmonic freq.
(60Hz, 120Hz, 180Hz, ...)

$$x(s) = \left\{\frac{\sqrt{\beta_S \beta(s)}}{2\sin\pi\nu}\cos\left[\left|\psi(s)-\psi_S\right|-\pi\nu\right] - \frac{\eta_S \eta(s)}{\alpha L_0}\right\}\theta_S$$

agreed with expected COD
for IB ripple ; $\Delta B/B < 4\mathrm{X}10^{-7}$

Pathlength ripple & RF ripple

Forced Oscillation

pathlength ripple

$$\frac{d\tau}{dt} = -\alpha_1 \varepsilon + \Delta_C e^{j\omega t}$$

RF ripple

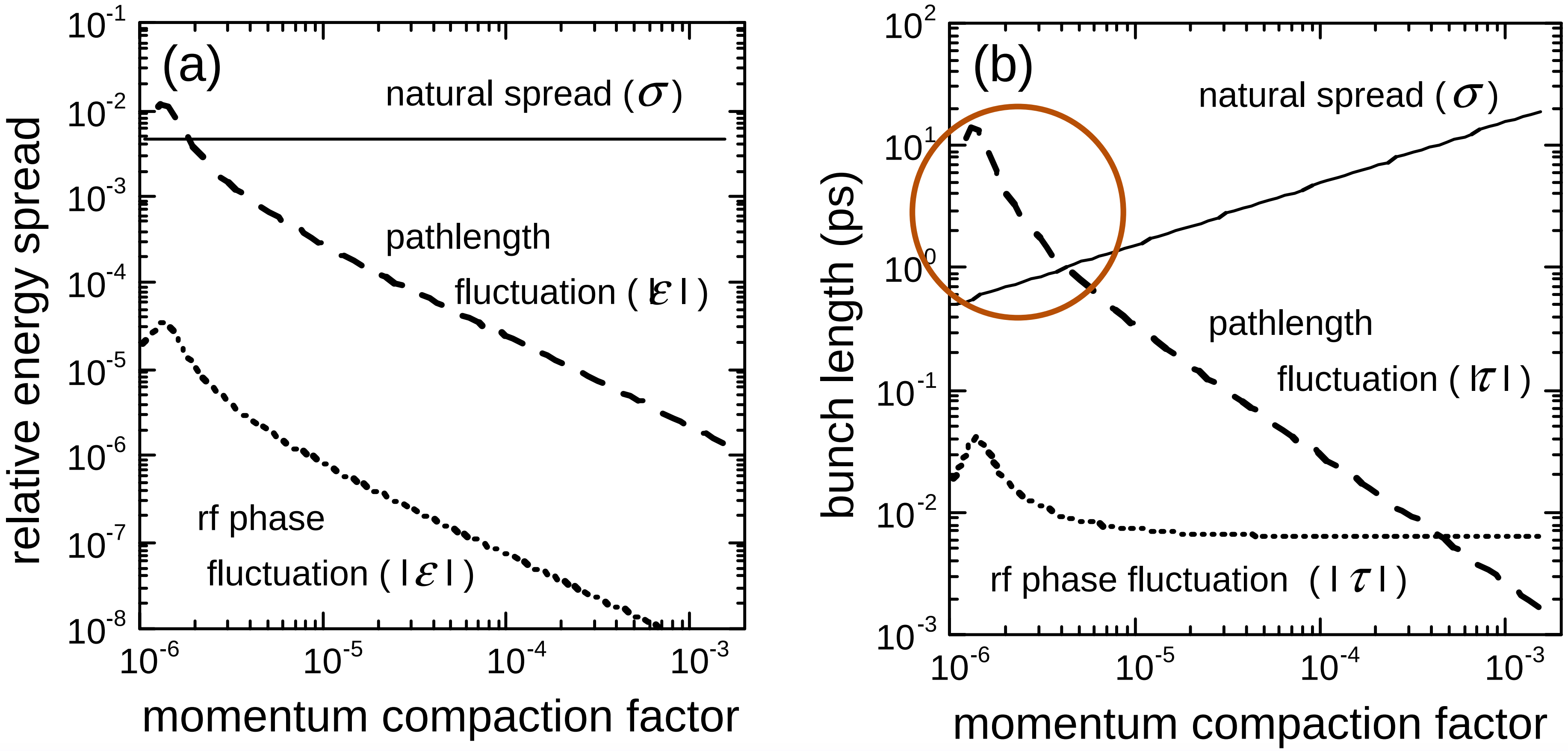
$$\frac{d\varepsilon}{dt} = \frac{\omega_S{}^2}{\alpha_1}(\tau + \Delta_P e^{j\omega t}) - 2\alpha_E \varepsilon$$

$$\tau = \frac{(2\alpha_E + j\omega)\Delta_C - \omega_S{}^2 \Delta_P}{\omega_S{}^2 - \omega^2 + 2j\omega\alpha_E} e^{j\omega t}$$

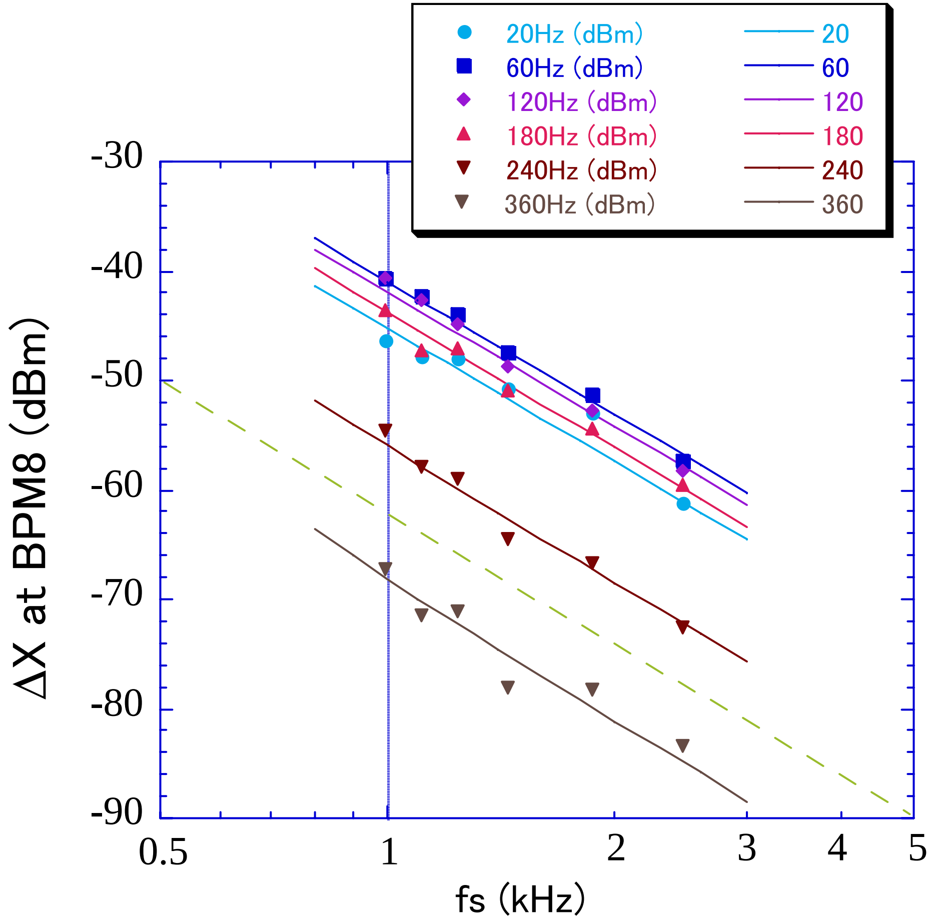
$$\varepsilon = \left(\frac{\omega_S{}^2}{\alpha_1}\right) \frac{\Delta_C + j\omega\Delta_P}{\omega_S{}^2 - \omega^2 + 2j\omega\alpha_E} e^{j\omega t}$$

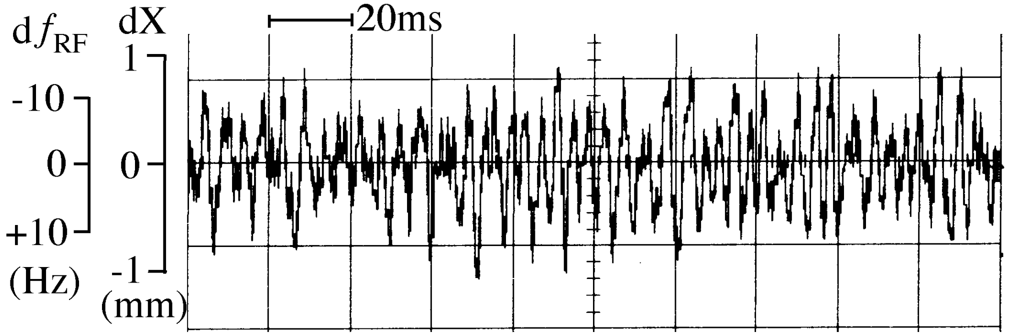
Pathlength ripple & RF ripple

(180 Hz)



Measured energy fluctuation (1)





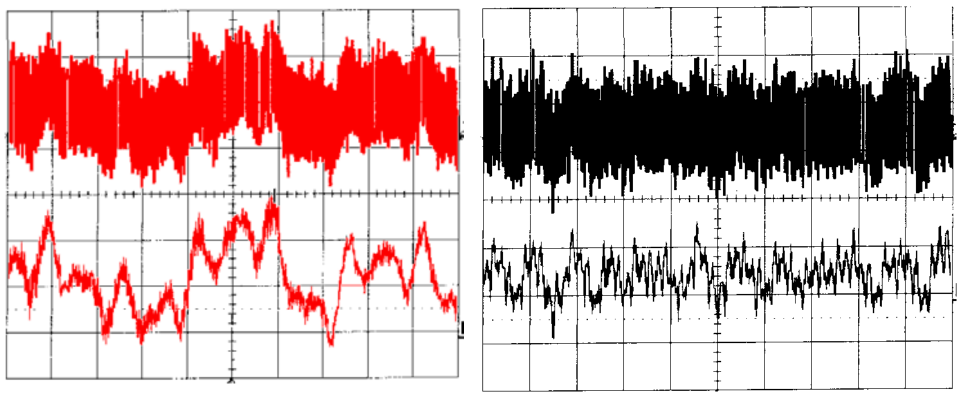
The oscillation is harmful

BESSY & ANKA have
no Invert Bend !

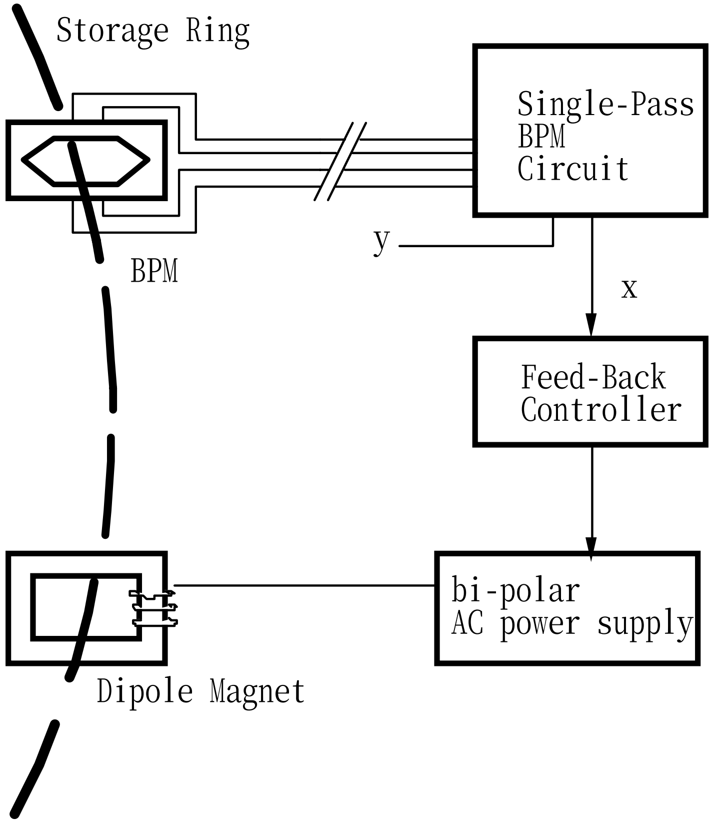
Feed-back control

Energy feed-back

Feed-back OFF ON



(below; with LPF; x2)

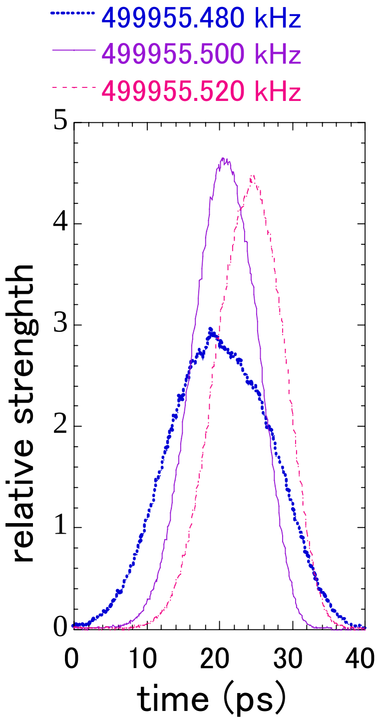


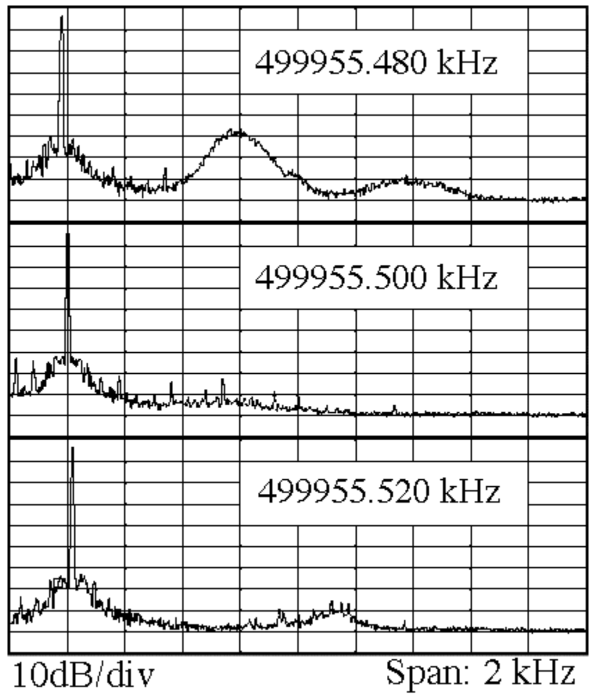
FB works at normal α_1

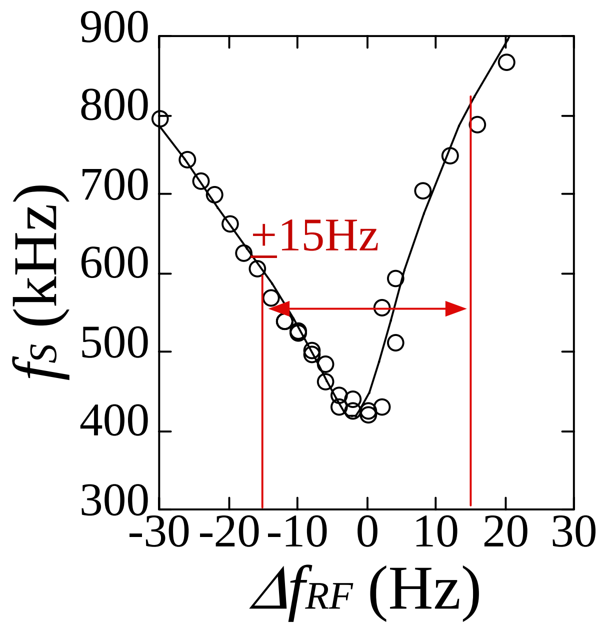
but not at small α_1 because of non-linearity?

Non-symmetry for +ΔE and -ΔE

The bunch length was not always shortest at where the f_S was the smallest. It strongly depended on δ (or Δf_{RF}) at small α_1 ($\alpha_1 = 1\times10^{-5}$).





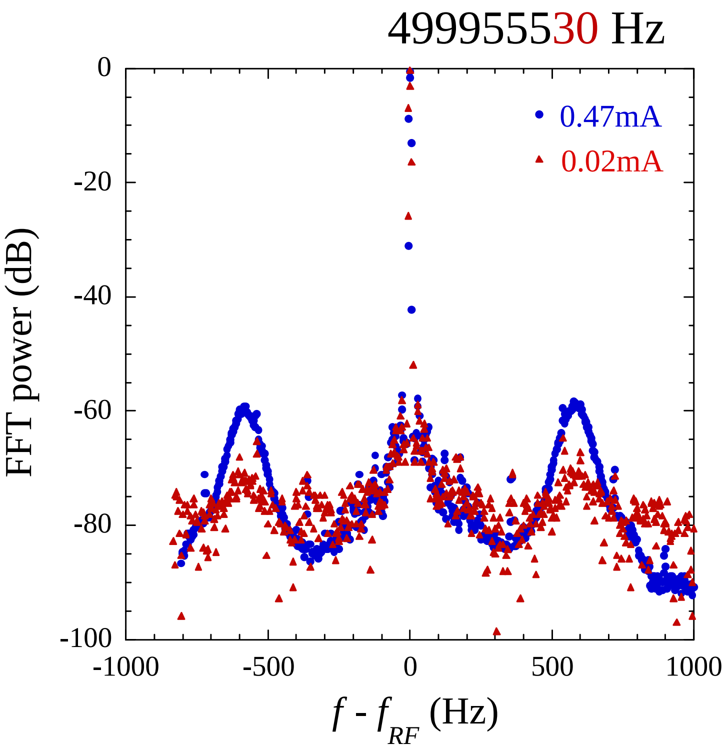


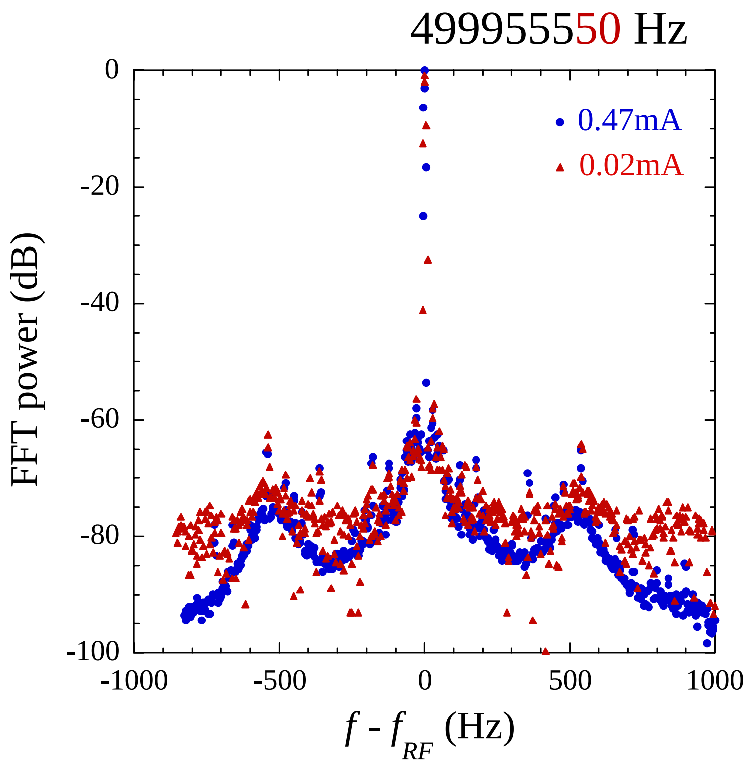
bunch shape. FFT spectrum of the beam signal

Synchrotron Oscillation is enhanced at δ>0

Non-symmetry for +ΔE and -ΔE

Non-symmetry has stored current dependence





Current dependence of fs side-band. f_{RF} peak is normalized to 0dB. White noise is subtracted from the data at 0.02mA

Conclusion

- Some problems in QI operation are enhanced at NewSUBARU probably because of the Invert Bend.

  - Ring stability is a main technical point of QI operation
  - Higher order α would be the other problem
    - Still there is a phenomenon not understood.