

Recent development in orbit stability and the feedback system at KEK Photon Factory and PF-AR

T. OBINA / Photon Factory, KEK

1-1 Oho Tsukuba, Ibaraki Japan

Overview

- ◆ Group/Member
 - ◆ Control: T.Obina
 - ◆ Monitor: T.Honda, K.Haga, M.Tadano
 - ◆ Magnet: Y.Kobayashi, K.Harada, T.Miyajima, S.Nagahashi
 - ◆ ID: S.Yamamoto, K.Tsuchiya, T.Shioya
 - ◆ Head of Light Source division: T.Kasuga
 - ◆and many other contributors....

1) Photon Factory(PF)

1-1) Orbit stability

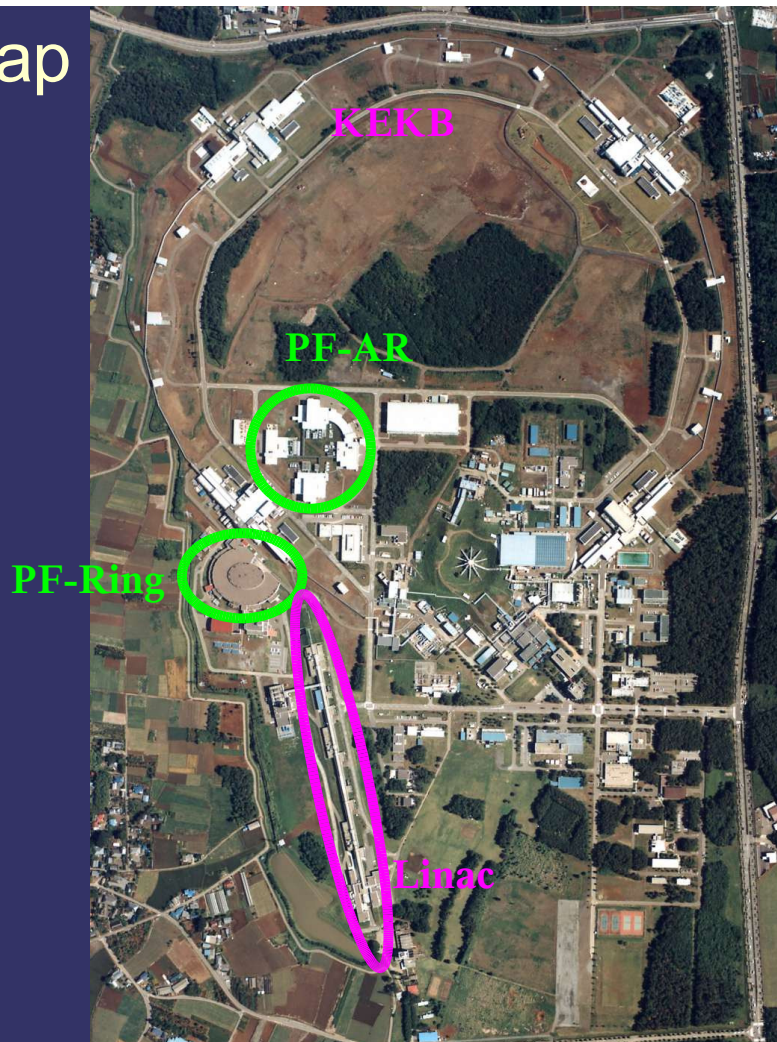
1-2) Feedback system for new undulator

2) PF-AR(PF-Advanced Ring)

2-1) Orbit stability

2-2) Injection with Pulsed-Quadrupole Magnet

KEK Site Map



Main Parameters

		PF	PF-AR
Energy	E [GeV]	2.5	6.5
Circumference	C [m]	187.07	377.26
Emittance	ϵ_0 [nm \times rad]	35.78	295.17
Energy Spread	σ_E/E	7.28474E-04	1.14586E-03
Momentum Compaction	α	6.16870E-03	1.27625E-02
Betatron Tune			
horizontal	ν_x	9.66	10.15
vertical	ν_y	4.25	10.19
Synchrotron Tune	ν_s	0.0142295	0.0567625
Chromaticity			
horizontal	ξ_x	-12.570	-14.250
vertical	ξ_y	-11.529	-13.159
Energy Loss	U_0 [keV/rev.]	398.853	6660.751
Damping Time			
horizontal	τ_x [msec]	7.787	2.454
vertical	τ_y [msec]	7.822	2.457
longitudin	τ_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	σ_z [mm]	9.40128	15.40534
RF Bucket Height	$(\Delta E/E)_{RF}$ [%]	1.217590	0.992220

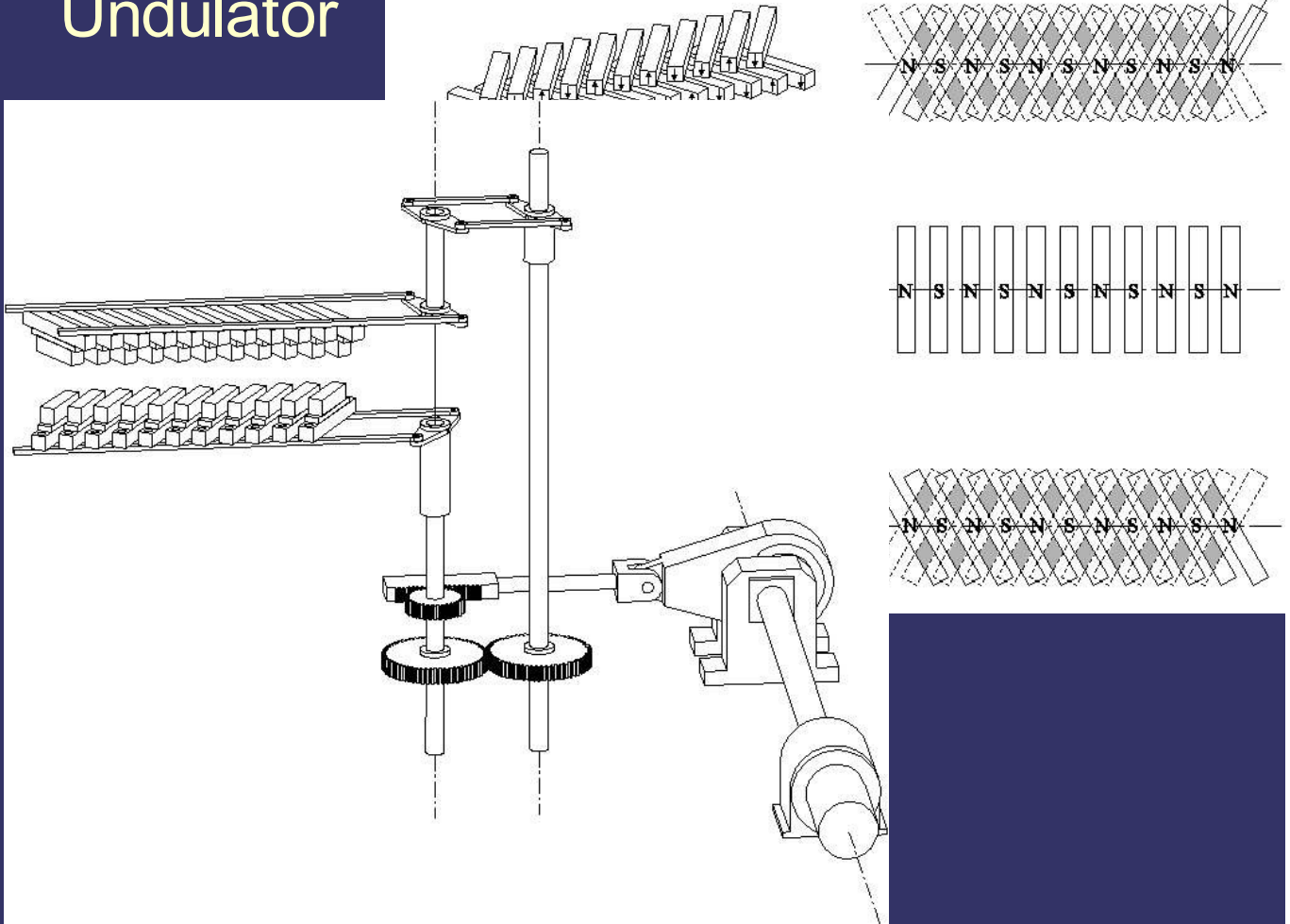
1-1) Orbit Stability at PF-Ring

- ◆ Fast orbit feedback system works very stably
 - ◆ Global Feedback Cycle: 12ms
 - ◆ BPM resolution: 3 μ m(peak-peak, 1sec)
 - ◆ Please refer to IWBS2002 proceedings
- ◆ There are no significant improvement after IWBS 2002 except for...
 - ◆ Increase # of eigenvalues: 8 -> 12
 - ◆ Max 28 (65BPM x 28Correctors)
- ◆ New Project: Upgrade of straight section
 - ◆ Shutdown Mar/2005 - Sep/2005
 - ◆ Main purpose
 - ◆ Increase number of straight section
 - ◆ Magnet triplet -> doublet + short straight section
 - ◆ Number of IDs 7 -> 11 + 2 short
 - ◆ Replacement of VERY old instruments ... more than 20 years!!
 - ◆ number of BPMs, Correctors will be increased
 - ◆ We are now designing new data acquisition system

1-2) Local Feedback System for New Undulator

- ◆ New Undulator for circular-polarized beam
 - ◆ Switch right-handed/left-handed/linear polarization
 - ◆ Use mechanical switching
 - ◆ not Apple-II type
 - ◆ Chevron switch
 - ◆ Switching speed: 0.8Hz
- ◆ Unfortunately, this undulator was installed in the PF ring only for several months another undulator have been used for users operation.

Undulator



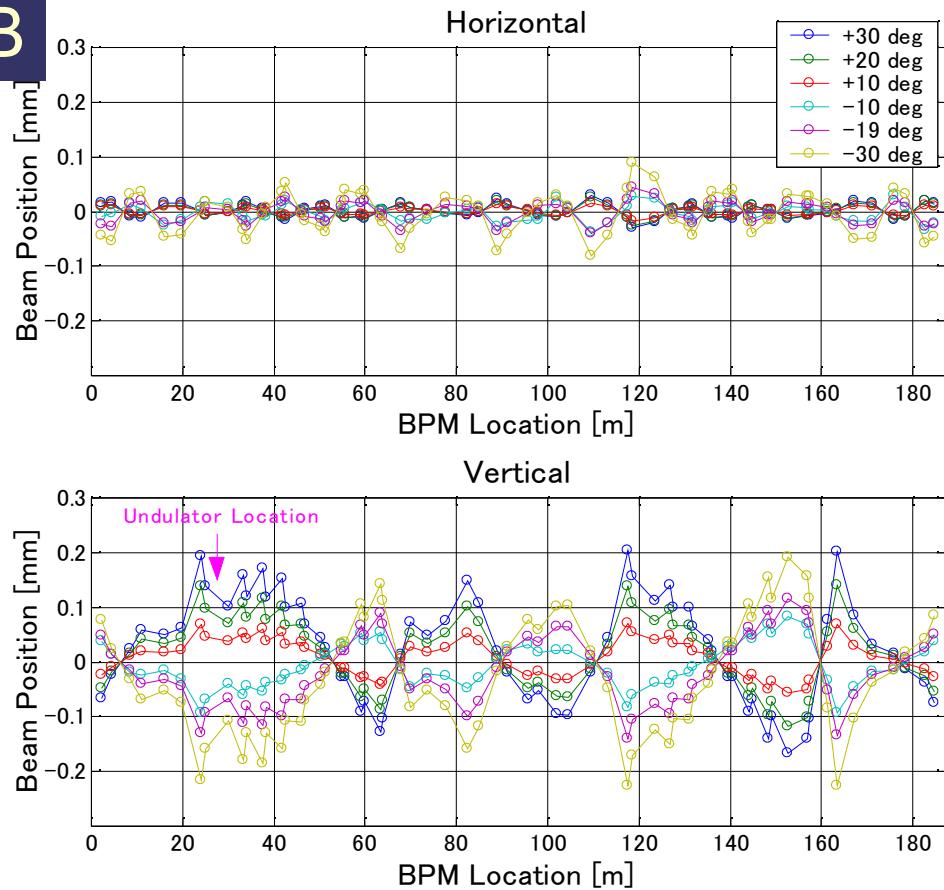
Movie

- ◆ External File

Movie1
An0106.mpg

Movie2
Testid03.mpg

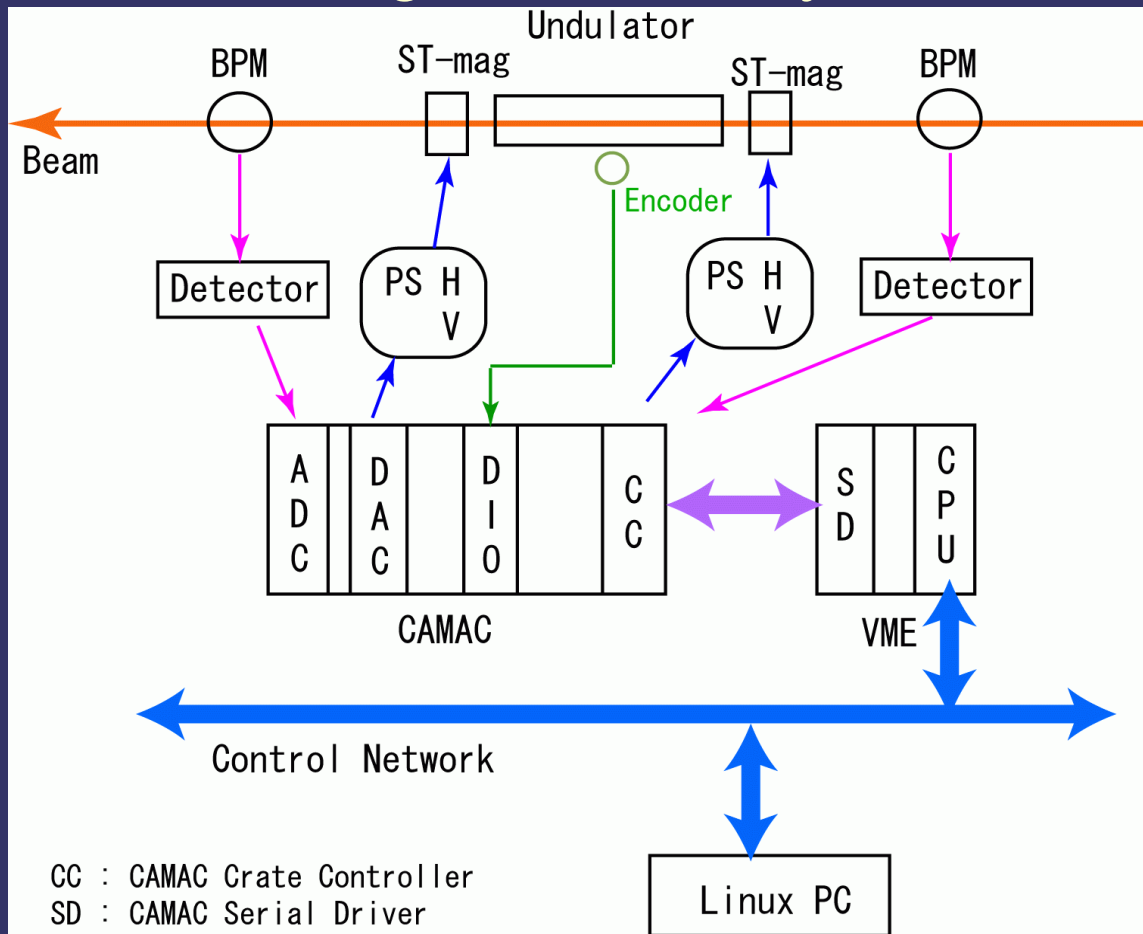
Result: without FB



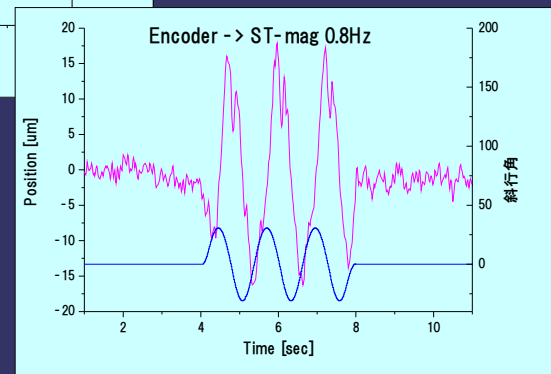
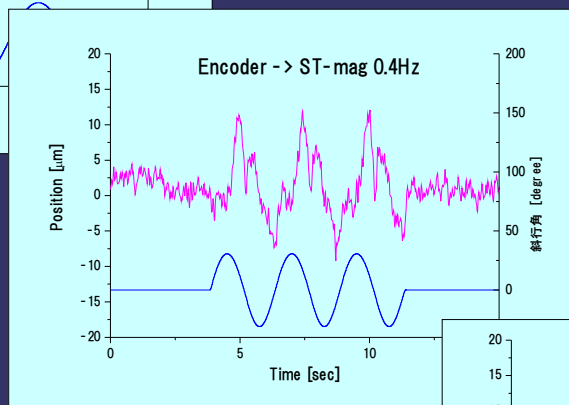
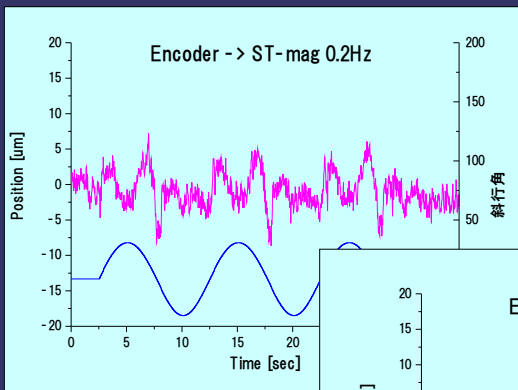
FB system

- ◆ Limitation:
 - ◆ No time/budget.....
 - ◆ We used existing CAMAC modules
 - ◆ FB cycle 50Hz
 - ◆ No start trigger for encoder output
 - ◆ GPIB control only
- ◆ Control/Data Acquisition
 - ◆ EPICS based system

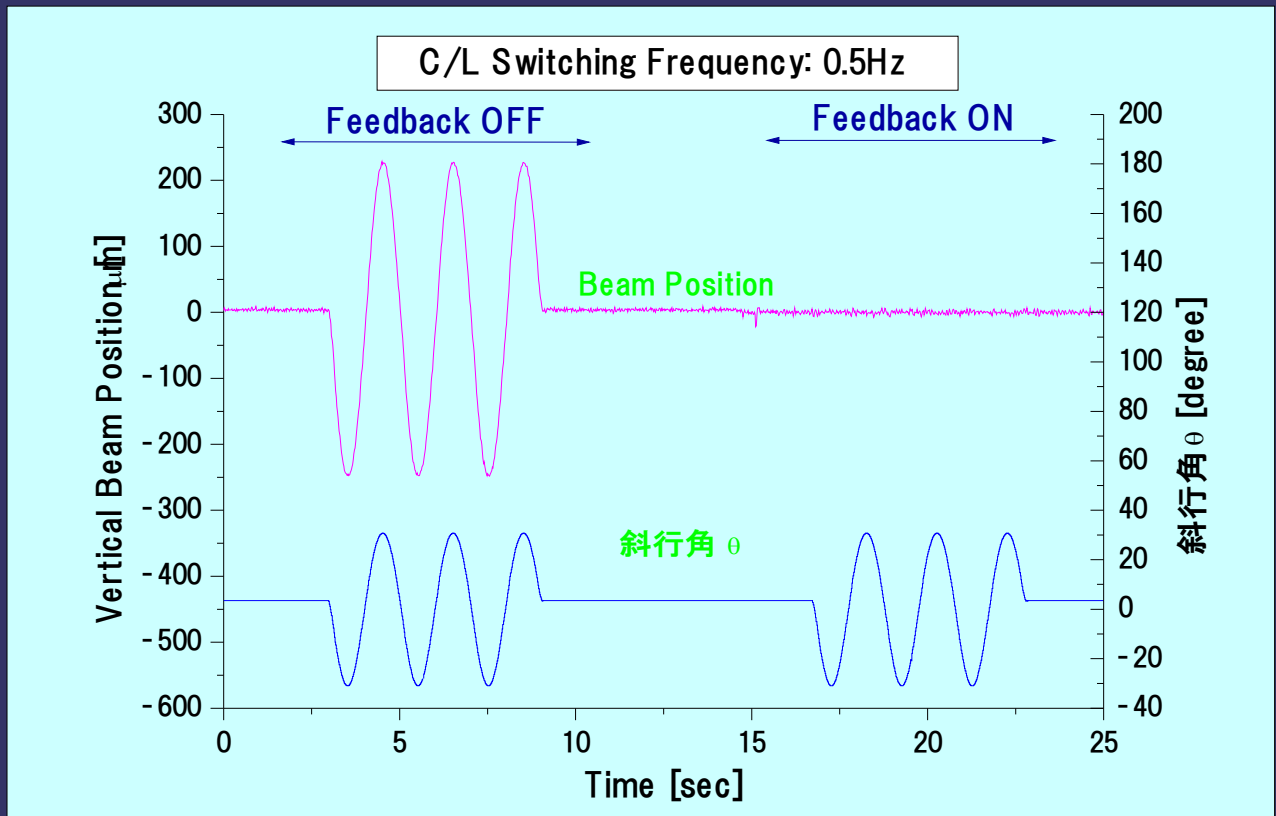
Block Diagram of FB System



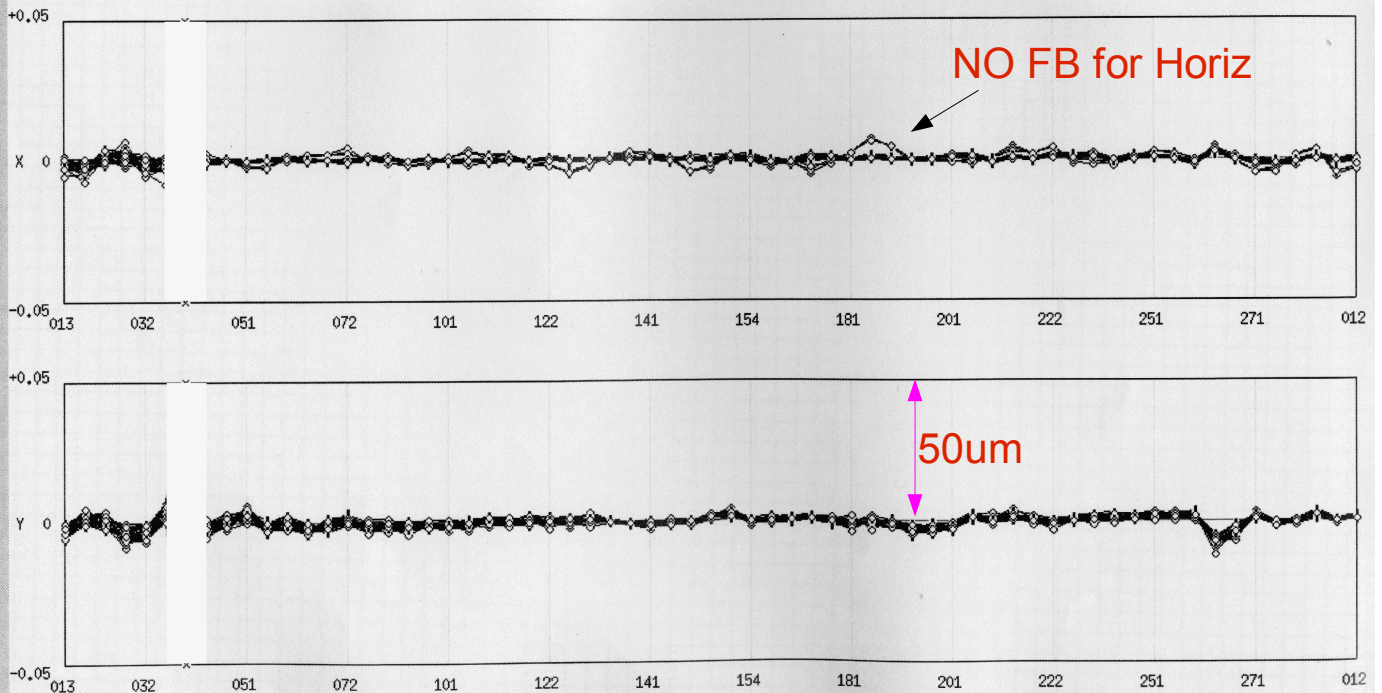
Result: Feedforward with Encoder



Feedforward+Feedback



COD with FB



現在時刻 : 2003. 6. 16 17:22:32
 上書開始時刻 : 2003. 6. 16 17:22:06

X Scale(±) 0.05 mm
 Y Scale(±) 0.05 mm

ビーム位置の表示方法 ビーム位置の絶対値 基準軌道の相対値
 : FB許可 : FB禁止

モード 書き換え 重ね書き 停 止

画面クリア

閉じる

Next step...

- ◆ This undulator will be installed in PF-AR
 - ◆ 1.5 year later
- ◆ Increase Encoder output resolution
 - ◆ 12bit -> 16bit
- ◆ Increase FB cycle
 - ◆ 50Hz -> 1kHz
 - ◆ ADC+FPGA+DAC system on cPCI (PXI)
- ◆ Improve analog front-end circuit

- ◆ How to avoid the interference of Global Orbit FB?
 - ◆ PF-AR : no problem
 - ◆ slow COD measurement/correction in every 10sec

2-1) PF-AR Status

- ◆ More than 20 year old machine

- ◆ PF-AR Upgrade Project in 2001
 - ◆ Replace Vacuum duct => Increase lifetime
 - ◆ Increase number of ST-mag => Orbit correction
 - ◆ No (or limited) budget for
 - ◆ Power supply of large magnet (B,Q,S)
 - ◆ RF Cavity
 - ◆ BPM electronics/Fast orbit correction

- ◆ We are still using
 - ◆ Old BPM-switching system
 - ◆ Replaced Mechanical SW->Mercury SW
 - ◆ Reliability of the measurement is greatly improved!!
 - ◆ Old detection circuit
 - ◆ We can measure/correct COD in every 10sec

2-2) PF-AR Injection system with Pulsed Quadrupole Magnet

- ◆ Advantage of PQ-Magnet Injection system
 - ◆ Only 1 magnet is enough for beam injection
 - ◆ Easy operation
 - ◆ Accuracy of manufacturing is not severe
 - ◆ Cost effective
 - ◆ No need for the Injection bump
 - ◆ No coherent oscillation on the stored beam



New Global Standard
for Top-up Injection!!

Why Pulsed-Q injection in PF-AR?

- ◆ In PF-AR, top-up injection is **IMPOSSIBLE** due to the limitation of beam transport line.
 - ◆ Injection: 3GeV / Users operation: 6.5GeV
- ◆ Coherent oscillation of the stored beam will produce the wakefield
 - ◆ Limit the maximum beam current : 65mA

↓ We are interested in:

Can we inject the beam with 1 Pulsed-Q magnet?
Can we break the upper limit of the stored current?

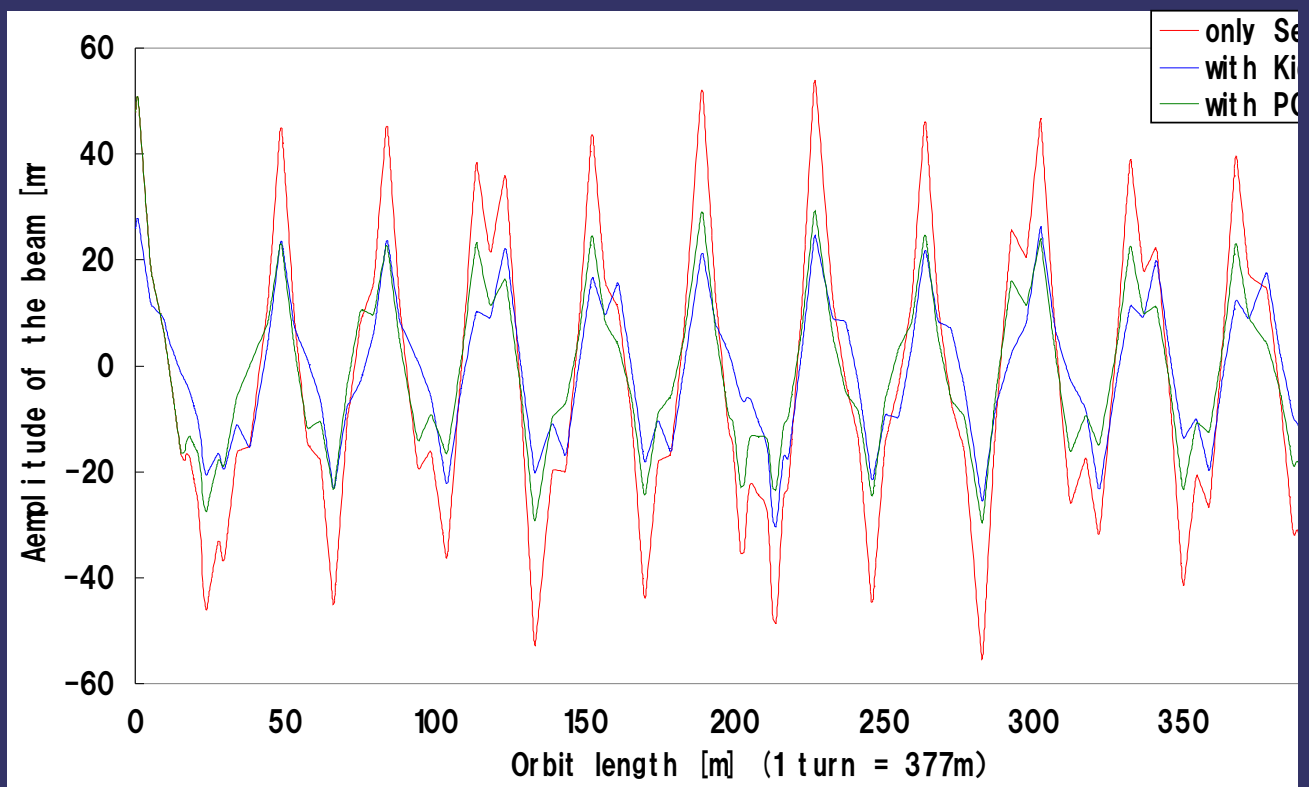
↓ Next step:

Test top-up injection at the other facility

Principle of PQ injection

- ◆ A quadrupole magnet has zero field strength at the magnetic pole center and the field strength is proportional to the amplitude of the beam.
 - ◆ Stored beam -> passing through center -> no kick
 - ◆ Injected beam -> off-axis orbit -> kicked
- ◆ Without using the bump orbit by 4- (or 3-) kicker magnets, we can inject the beam.

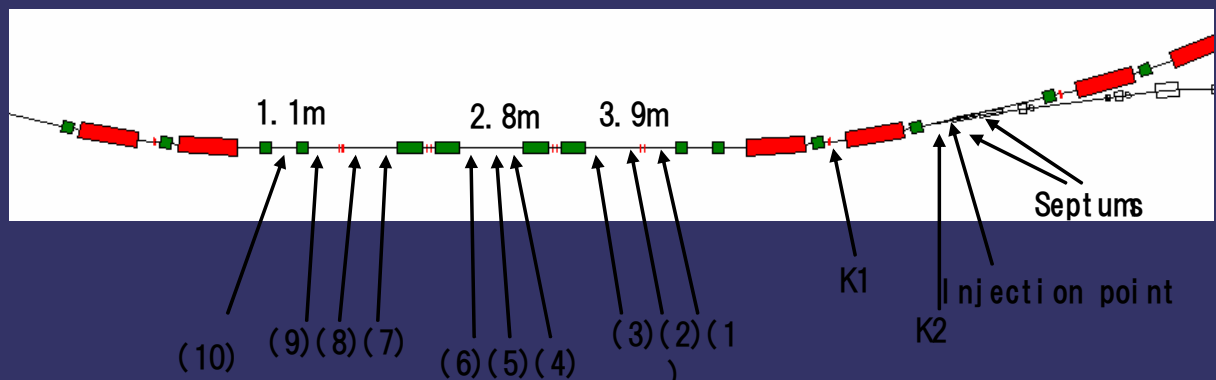
Orbit of injected beam



- ◆ Amplitude of injected beam: almost same as kickers

Optimization of PQ location

- ◆ The oscillation of the injected beam is almost linear even with large amplitude at PF-AR. We can consider the oscillation of the injected beam as a "harmonic oscillator" by using Courant-Snyder invariant (injection emittance).
- ◆ We must install before the amplitude of injected beam becomes to its maximum value.



Main Parameters of Pulsed Q magnet

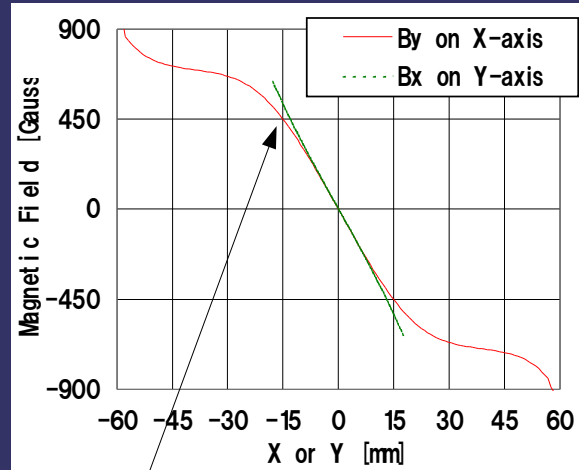
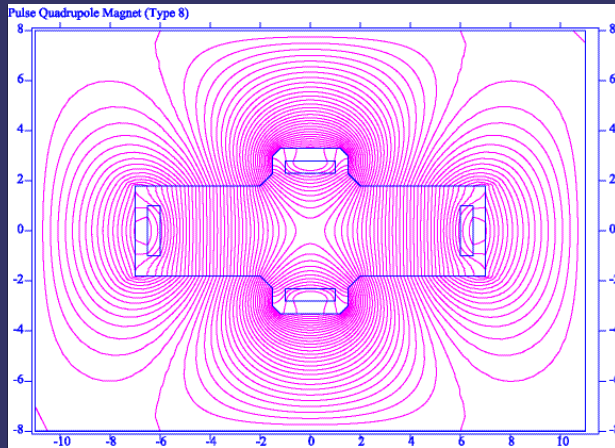
Magnet

Length	300	mm
vertical bore	36	mm
Horizontal bore	104	mm
turn number	1	turn
number of coils	4	
field gradient	3	T/m
current	2000	A
peak current	4000	Ap
inductanc	1.8	uH

Power Supply

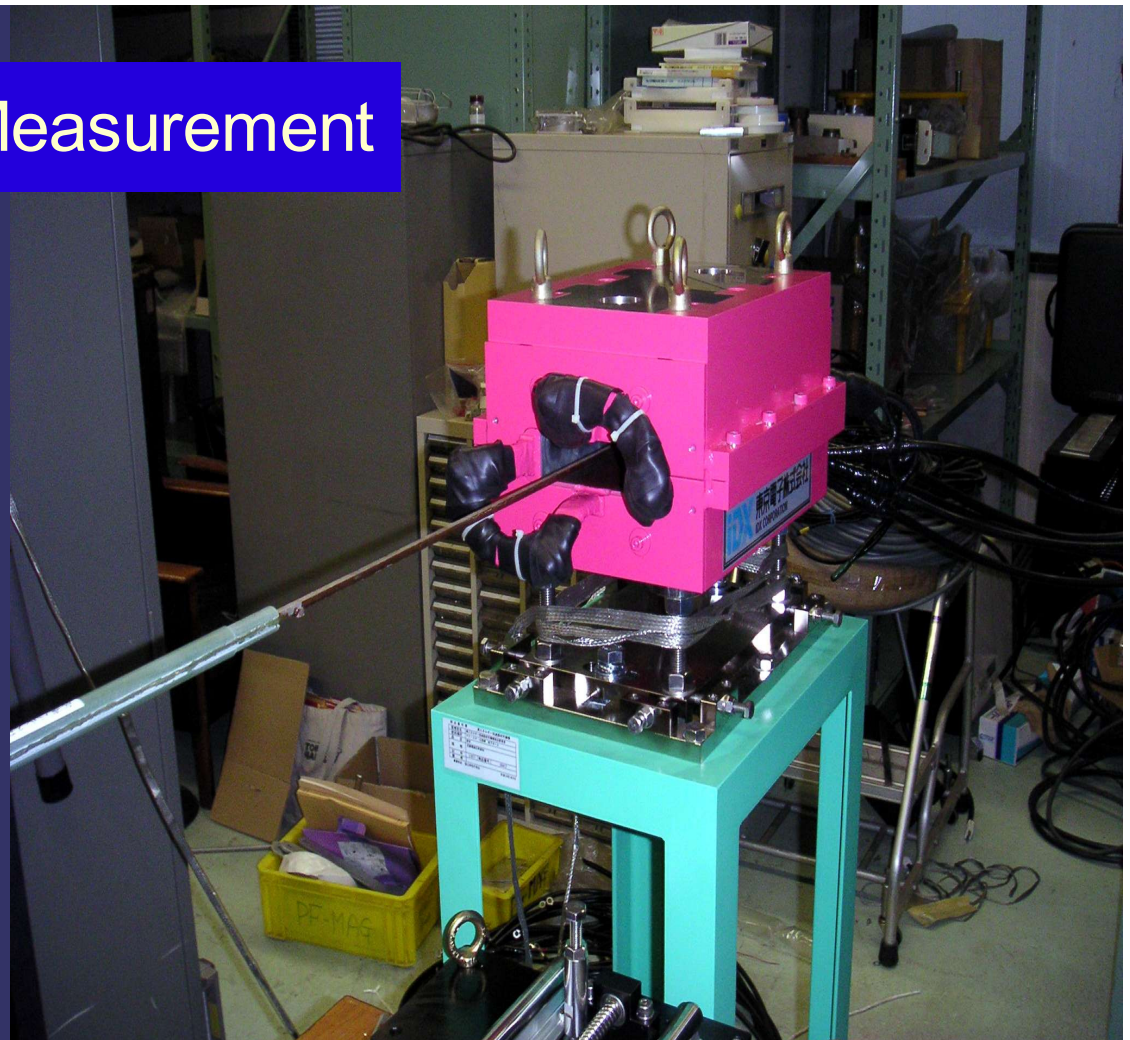
output current	-4000	A (peak)
Pulse shape	half sine,	25PPS
Pulse width	2.4	usec

Field Calculation

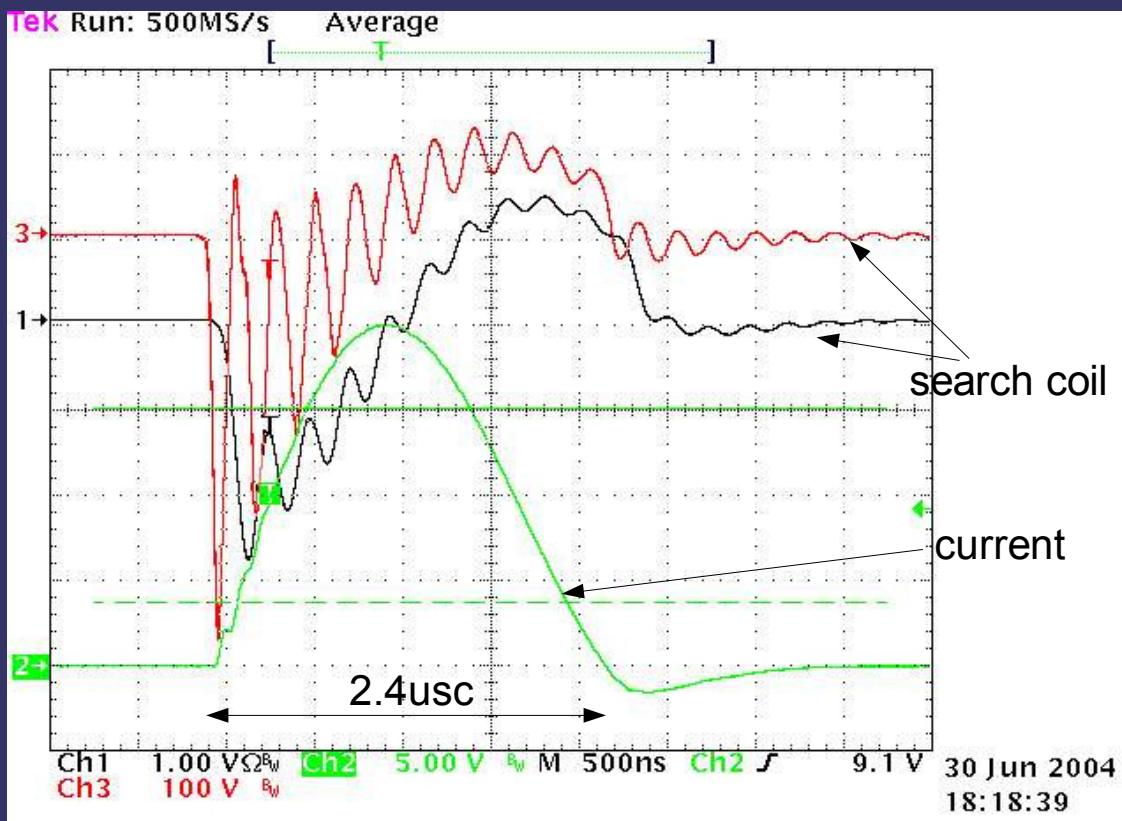


450 Gauss = 3T/m, at 15mm
1.1mrad kick

Field Measurement



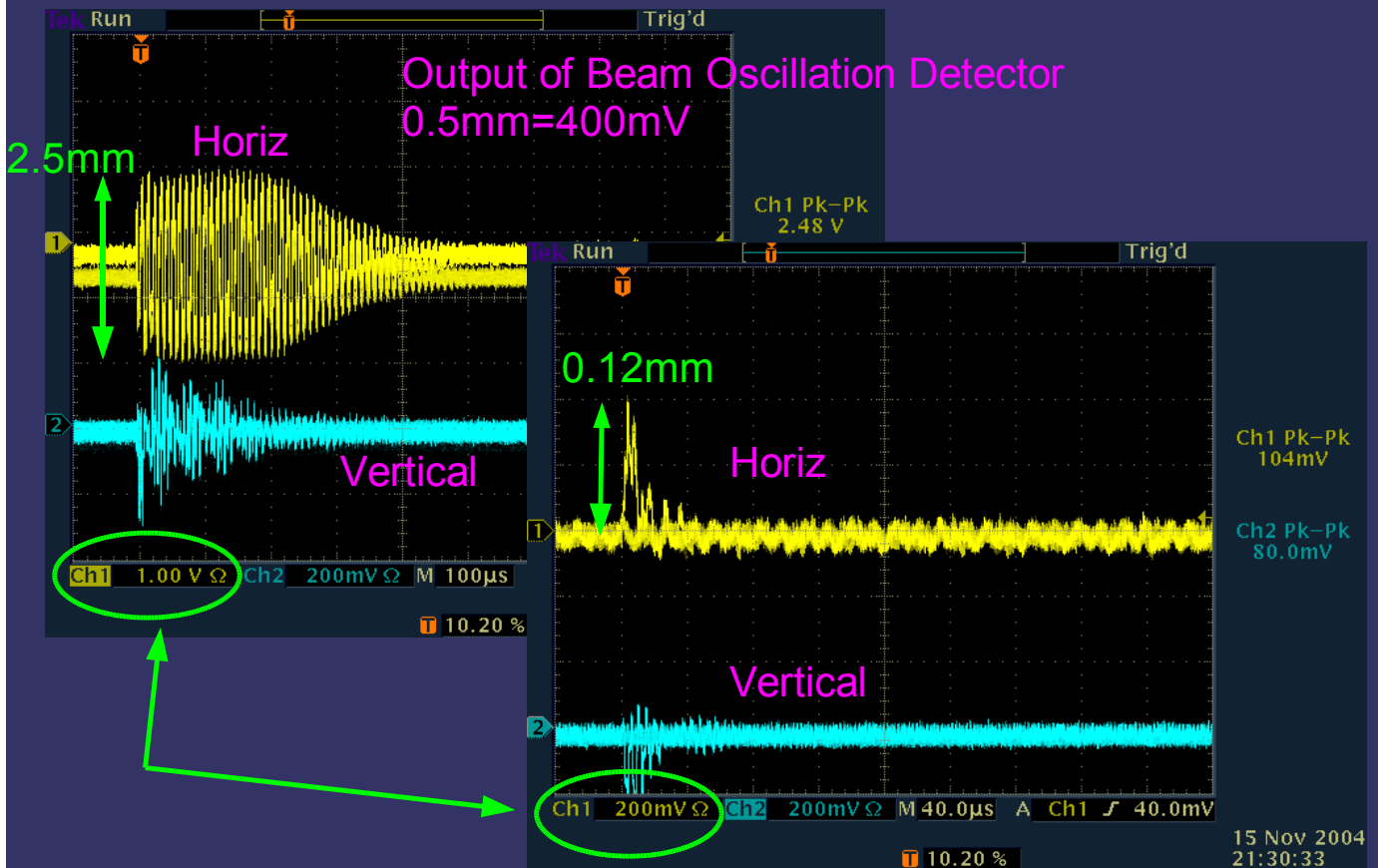
Typical Pulse Shape



Installation and Beam Test

- ◆ Summer/2004
- ◆ Installed at south straight section of PF-AR
- ◆ Pulse shape have modulated a little because the cable length between PQ and PowerSupply is not equal to the optimum length due to the limitation of the location (for now).
- ◆ Beam Test
 - ◆ 15/Nov/2004 and 29/Nov/2004
 - ◆ total 12Hrs
 - ◆ with stored beam
 - ◆ with injected beam
- ◆ Preliminary result next page

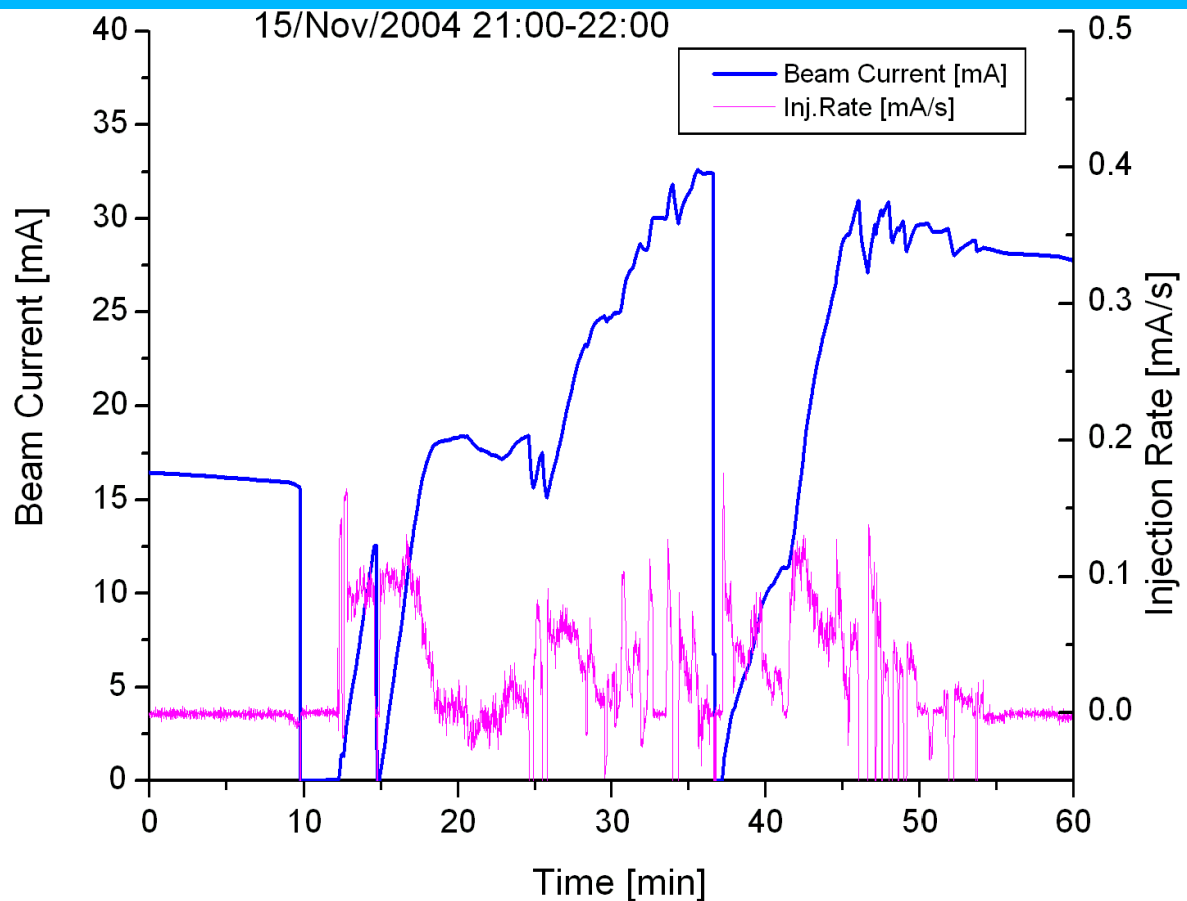
Result: Oscillation of Stored Beam



Beam Current

- ◆ Local bump were applied in order to match the center of PQ magnet and the position of the stored beam.
- ◆ Amplitude of the stored beam have been reduced!
- ◆ Residual oscillation still exists.... we will try again
 - ◆ We had some trouble in orbit correction system during the experiment....
- ◆
- ◆ We can inject over 30mA (next page)

Beam Current : We can Inject with PQ only



Next step ...

- ◆ Continue machine study
- ◆ Optimize local bump orbit
- ◆ Maximize beam current/injection rate
 - ◆ maximum current is smaller than the normal operation at the last experiment. we will investigate more.
- ◆ Next week:
 - ◆ Observation of injected beam with fast gate camera