Beam Diagnostics

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3. Bunch by bunch feedback system
4. Synchrotron Light Monitor
5. Gated Measurement
6. Summary

1. Introduction

•Parameters of SuperKEKB related to the beam diagnostics

	HER	LER	Related monitors
Energy (GeV)	7	4	
Current (A)	2.6	3.6	BPM, FB, SRM
Number of bunches	2503	2503	FB, SRM
Single bunch current (mA)	1.0	1.4	BPM,FB, SRM
Bunch separation (ns)	4	4	BPM, FB, SRM
Bunch length (mm)	5	6	FB, SRM
Emittance (nm)	2.4	3.2	BPM, FB, SRM
Coupling (%)	0.35	0.4	BPM, FB, SRM
Vertical beam size at IP (nm)	59	59	BPM, FB
Transverse damping time (ms)	56	37	FB
Vacuum chamber	ante-chamber	ante-chamber	BPM, SRM

Beam current is twice as much as that of KEKB is.

Very small beam size, especially in vertical plane.

BPM : Beam position monitor

FB : Bunch feedback

SRM : Synchrotron radiation monitor

2. Beam position monitor

Requirement

- Requirement to the BPM system is not fully specified yet.
- In order to start R&D we tentatively assumed that the required resolution of the measurement is not far from the performance in present KEKB.

  Resolution : several micron, accuracy : 40 micron (by beam based alignment)

Tentative functional specification

- Precise slow measurement - Repetition of ~1Hz.
- Fast orbit measurement for the orbit stabilizing feedback whose repetition rate is several kHz.
- Optics measurement during physics

  Turn by turn orbit measurement of a pilot bunch to obtain betatron phase and X-Y coupling.
- Fast orbit feedback to maintain stable collision.

Factors affecting system design

a) Large beam current

•Large signal power to a detector, poor electrical contact of an electrode and a cable and movement of BPM due to thermal deformation of a chamber.

b) Use of ante-chambers

•Lowest cut-off frequency of about 900 to 990MHz of a beam chamber is below a detection frequency in present KEKB system.

c) Maximal use of present narrowband detection system based on VXI to save the cost.

Design strategy

a) Development of a new button electrode.

Button with small diameter, pin type inner conductor

b) Development of a new detection module for 509 MHz detection.

c) Development of a medium-band detection module for orbit stabilizing feedback and gated turn by turn orbit measurement for optics measurement.

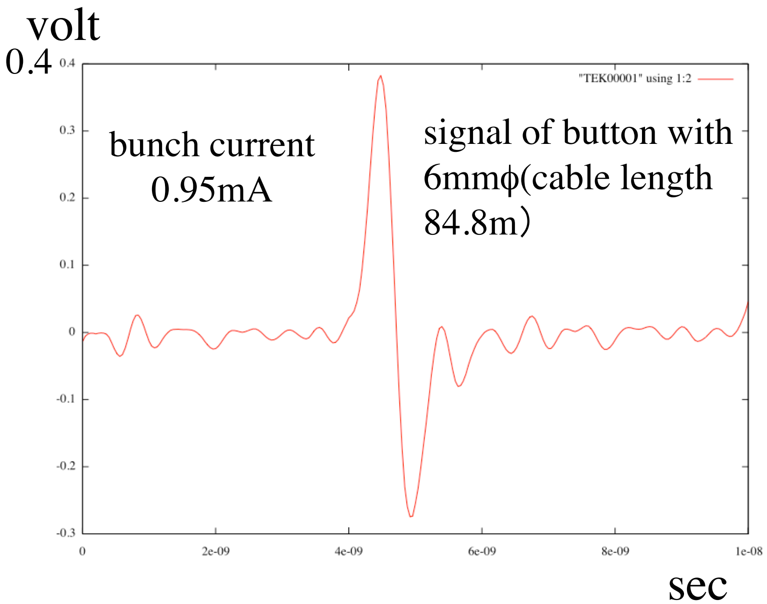
d) Development of a special detection module for collision feedback.

e) Use of displacement sensors to measure the movement of BPM due to thermal deformation of a chamber.

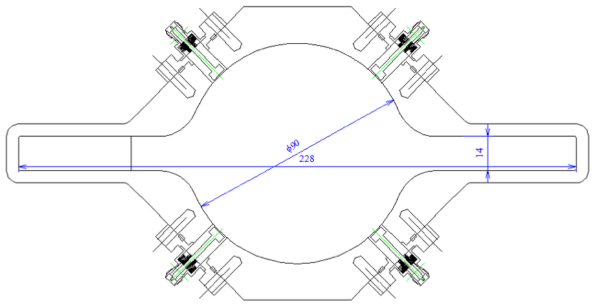
Button electrode

- A button electrode is under development.
  - ◊Diameter : 6mm
  - ◊Flange type for easy replacement upon trouble and TiN coating
  - ◊Pin-type inner conductor for tight electrical connection
  - ◊Ceramic vacuum seal

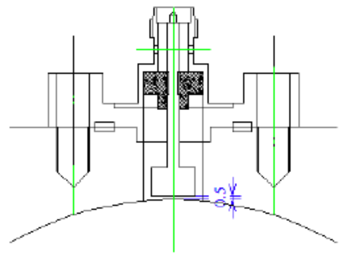
- Prototypes are installed in ante-chambers in Nikko straight section and the south tunnel for test. Problem is not found so far.

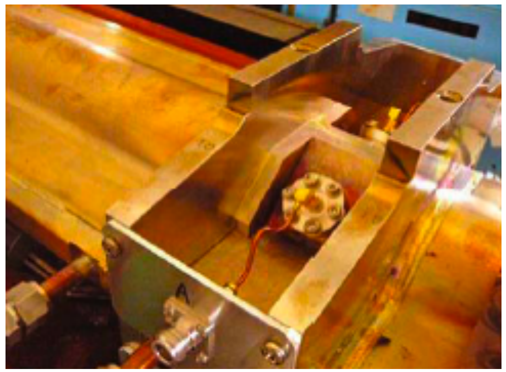


LER chamber



Electrode





509 MHz super-heterodyne detector

•A narrowband super heterodyne receiver is being developed based on a present detector.

•At the previous KEKB review committee, we reported that SNR of the detector was 60.9 dB at a bench (SNR 90 dB<-> resolution 0.5μm).

•Since then following improvements were taken.

◊A synthesizer to make a LO signal was replaced to that with smaller phase noise.

◊Gain of a RF amp in front of the mixer was increased.

◊Frequency characteristics of the IF filter was improved.

◊A switch module was renewed.

⇨ Relative SNR was improved to 88 dB by averaging data 8 times. ("Relatve" means signals of 4 channels are normalized by a signal level of a specific channel).

◊A bug in power calculation of FFT was fixed.

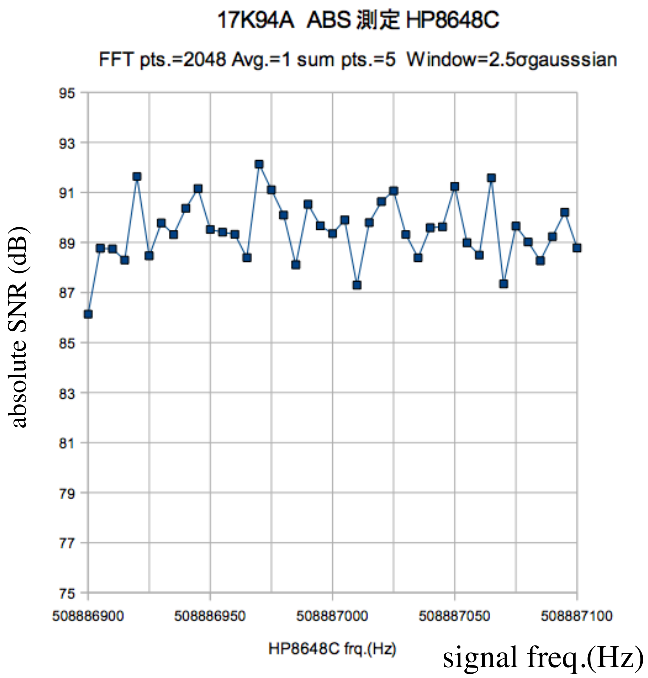
⇨ Absolute SNR was improved to 88 dB without averaging (a switch module was bypassed).

◊A switch module is being tested at a company.

◊The module will be tested by beam in this spring.

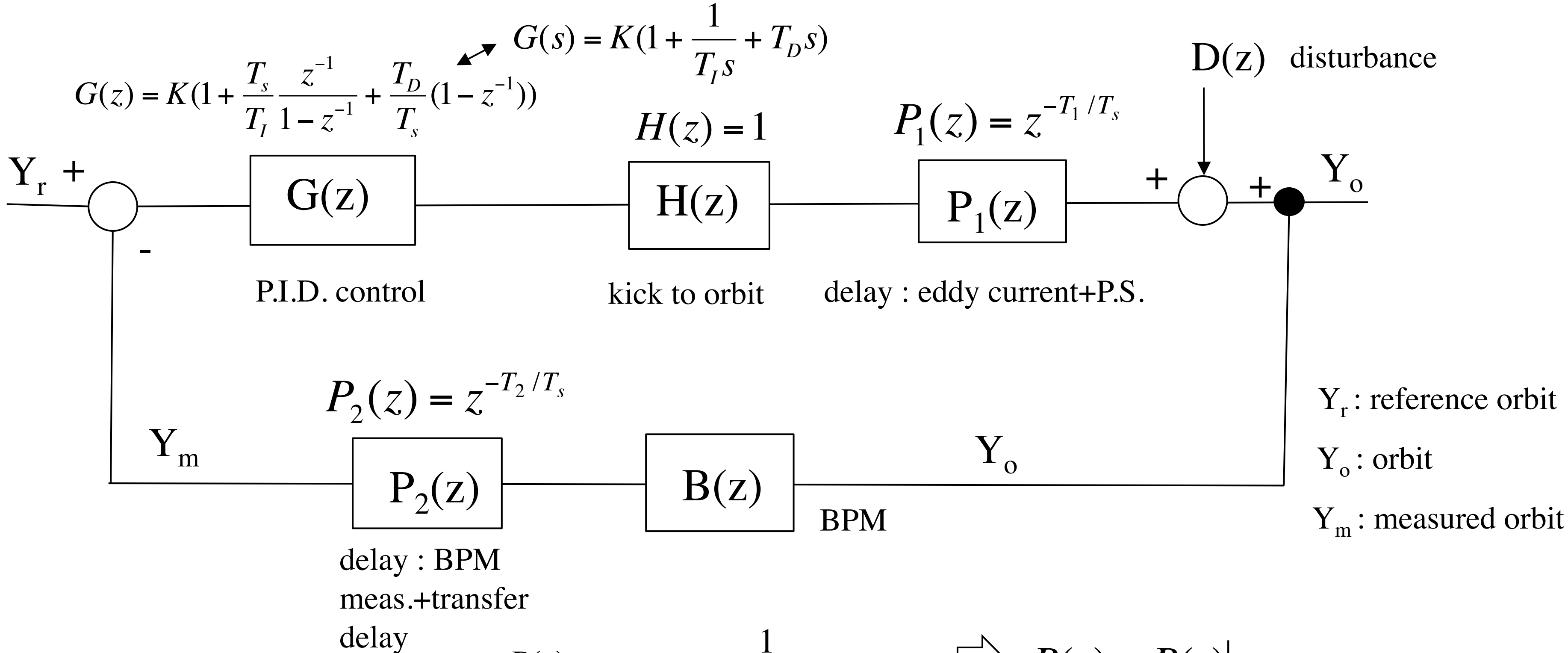
Specification

Detection frequency	508.887MHz
SNR at signal power of -60 dBm	> 89.8 dB
Noise figure	< 7 dB
ADC (bits/sampling freq.)	18 bits / 102.4 kHz
Max. input power	-50 dBm
FFT points (by DSP : SHARC)	2^N (N=4, 5, ..., 12)



Medium-band detector

•Simple feedback model to determine repetition frequency of orbit measurement



$$B(s) = \frac{1}{1 + a \cdot s/\omega_c + b \cdot (s/\omega_c)^2} \Rightarrow B(z) = B(s)\Big|_{s = 2/T_s (z-1)/(z+1)}$$

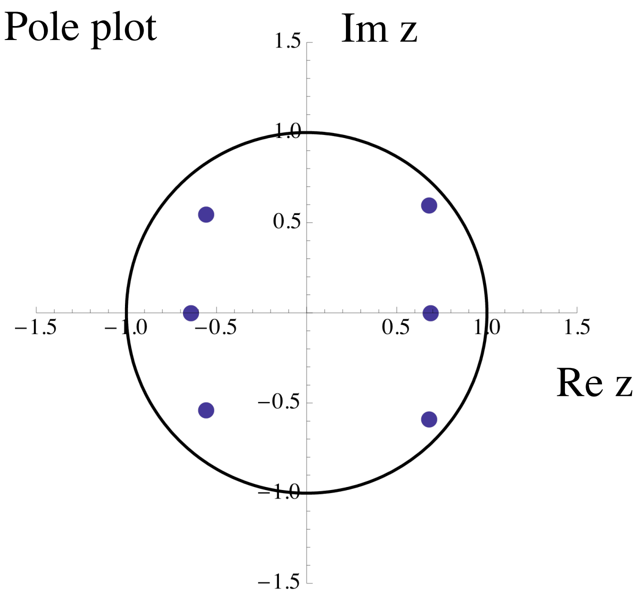
Bessel LPF : a=1.3617, b=0.6180

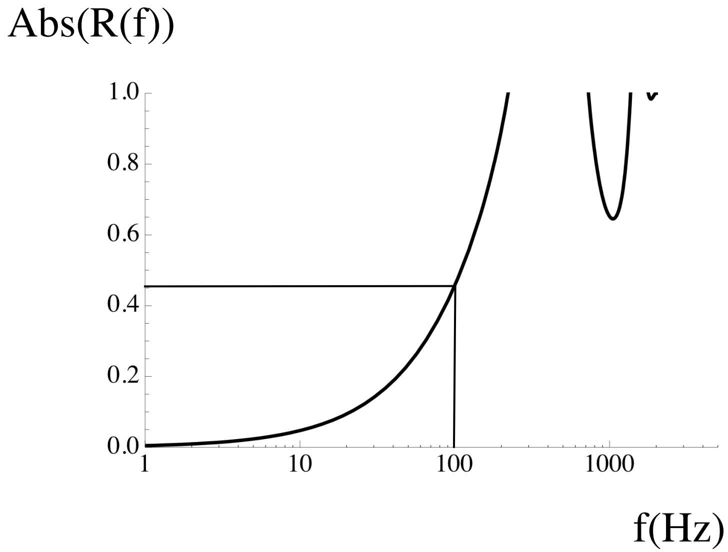
T_s : sampling interval

Transfer function from Disturbance to Orbit

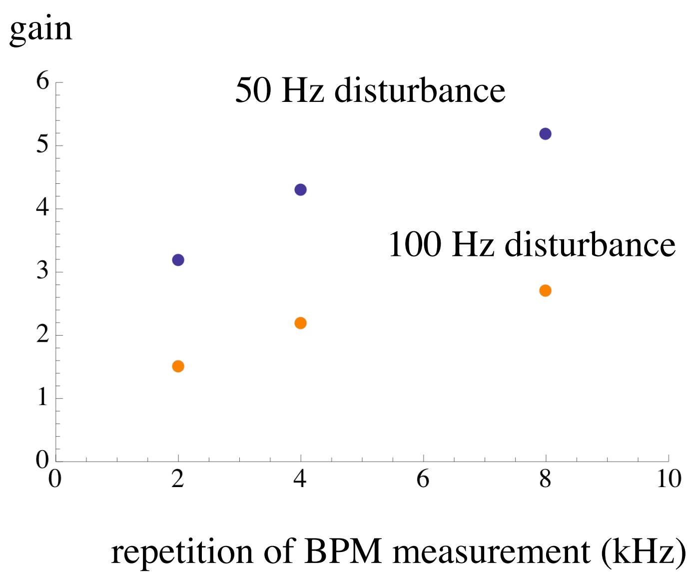
$$R(z) = \frac{Y_o(z)}{D(z)} = \frac{1}{1 + H(z)G(z)B(z)P_1(z)P_2(z)} \quad \text{for } Y_r = 0$$

T_s : 0.25ms, ω_c: 12.6kHz, T_1 : 0.5 ms, T_2 : 0.25 ms, T_I : 0.6 ms, T_D : 0 ms, K : 0.8





gain = 1/0.45 = 2.2 @ 100Hz



We set,

sampling freq. fs as 4 ~ 5 kHz.

⇨ Gain for 50 Hz disturbance of ~ 4.5.

- Evaluation circuit board for medium-band detector

◊An evaluation circuit board with FPGA (Virtex5) is under development.

◊Specification

- Direct detection of 509MHz component with a sampling ADC and a digital filter.
- Maximum repetition rate of 5 kHz for orbit stabilizing feedback.
- Averaging data for slow but higher resolution measurement with rep. rate of 10 Hz.
- Independent Log-Ratio detector with a fast gate switch (<6ns) with adjustable delay for turn by turn orbit measurement for optics measurement.

- Electrical

Input level	-10 ~ -3 dBm
Detection frequency	509MHz
ADC resolution	14 bits
ADC sampling frequency	98.4 MHz (det.) / 40 MHz (log. amp.)
Log amp.	dynamic range > 80dB, freq. range 0.4 ~ 4GHz
Repetition	5 kHz (max.)
SNR	>80 dB@-60dBm input and BW of 5kHz
Fast gate	width < 6 ns including rise and fall time

◊The board will be tested in this spring.

•Consideration to the standard BPM system

◊Cost is a big problem.

◊If a price of the midium-band detector is 20000$ / unit,
total cost is 20000$ x 938 units = 19M$.

◊Cost will be evaluated after the evaluation circuit is tested. Cost oriented optimization of the system will be taken into account.

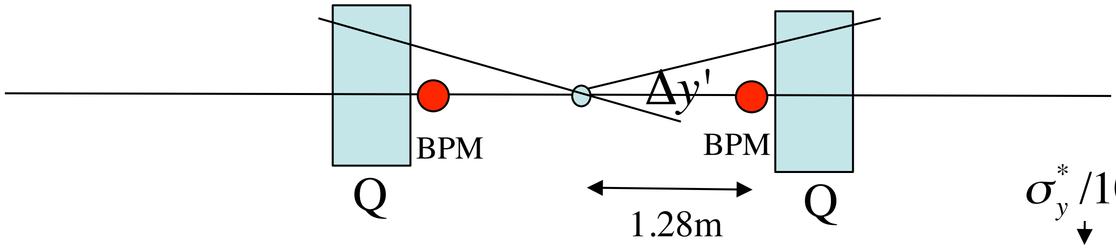
◊Use of the narrowband detectors together with the medium-band detectors may be a good compromise of cost and performance.

For example, the medium-band detectors for orbit feedback can be used for BPMs near sextupoles where optics will be sensitive to orbit deviation.

BPM for orbit feedback to maintain stable collision

•Simple consideration on the BPM resolution and repetition rate of the measurement

1) Resolution



◊Beam-beam kick $$\Delta y' = \frac{2\pi}{\beta_y^*}\xi_y \Delta y = \frac{2\pi}{0.27mm} 0.09 \cdot \overset{\sigma_y^* / 10}{\overset{\downarrow}{\boxed{\frac{59nm}{10}}}} = 12.4\,\mu rad$$

◊Orbit change at BPM $$\Delta y_{BPM} = 1.28 \frac{\Delta y'}{2} = 7.9\,\mu m$$

◊Required BPM resolution will be ~ 1 μm.

2) Repetition

◊Measurement of vibration of IR quadupoles (M. Masuzawa et al., IWAA2004)

Some peaks are seen at frequency less than 100 Hz.

Vertical oscillation amplitude whose frequency is larger than 50 Hz is less than 1/10 of beam size.

◊Feedback needs to have a gain in the region < 100Hz.

⇨ Required rep. rate of the measurement of ~ several kHz (e.g. 5 kHz).

•Signal processing of a detector

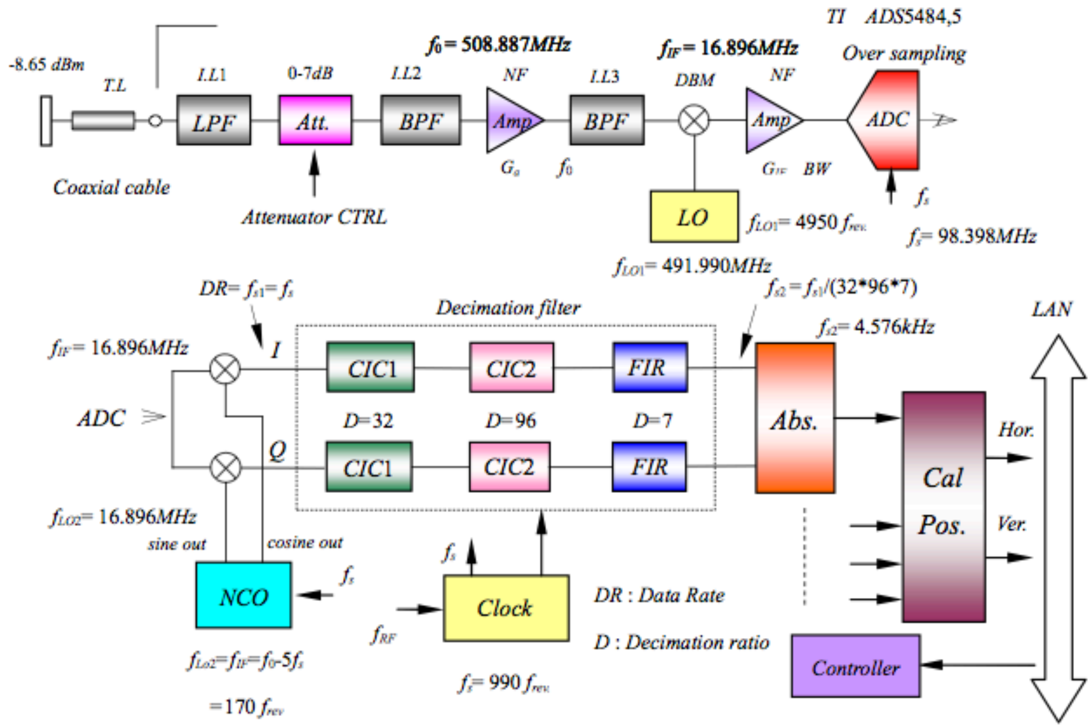
◊Intrinsic resolution from thermal noise is 6nm for BW of 1kHz.

◊Down covert 508.8MHz component of the beam to lower frequency with an analog mixer.

◊Convert IF to digital signal.

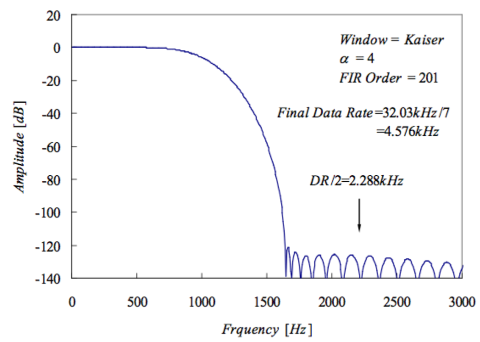
◊Detect position through digital filters (CIC+FIR).

SNR is relatively insensitive to a clock jitter than that in direct conversion though additional analogue RF circuit is needed.



An evaluation system is under development in this fiscal year.

Filter response (CIC and FIR)



Specification

Input level	-10 ~ -3 dBm
Detection frequency	509MHz
LO frequency	492 MHz
IF frequency	16.9 MHz
ADC resolution	16 bits
ADC sampling frequency	99.4 MHz
Sampling clock jitter (target value)	<1ps
CIC1	5 stage, decimation 32
CIC2	5 stage, decimation 96
FIR	201 tap, decimation 7
SNR	> 110dB@-2.65dBm sinusoidal wave
Control	EPICS

BPM noise at 509MHz

- The detection frequency is changed to 509 MHz from 1GHz of KEKB because antechambers will be used. Noise from RF system might be troublesome.
- 509 MHz signal was measured at Nikko straight section when RF cavities in HER were powered. The measurement showed that

◊The noise came through signal pass from a feedthrough to a detector (shown at the previous KEKB review committee).

◊The 508 MHz air waves enter from the klystron room to the control room.

At a module rack in the control room : 87dB μV/m, at a driver amp in the klystron room : 107dB μV/m.

◊Shielding of 9D coaxial cable is OK.

A cable with length of 12m was fabricated. The signal was measured by a spectrum analyzer when one end of the cable, which was terminated or covered by a meshed metal sheet, was put near the driver amp in the klystron room. The 508MHz signal was not observed.

◊The noise signal was detected by a VXI module in the shield tent where air waves were shielded.

⇨ The signal really comes through cables.

- Sources of a noise are still not identified yet.
- In operation the noise will be actually attenuated by an attenuator in the detector module which adjusts an input level of the signal. From the measured signal and noise level, degradation of the resolution is 0.045 / 0.7 μm at beam current of 1600 / 100 mA.

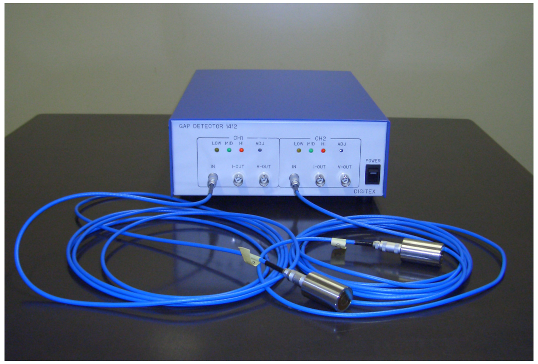
Noise voltage : V_n=1.7mV(rms) in 0 dB attenuator setting

Beam signal @ 1600mA : V_b=2.0V(rms) with 50dB attenuator setting

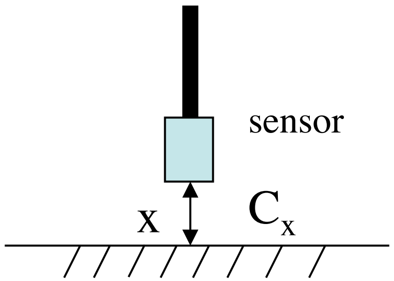
- Though the noise level will be small in usual operation, it may affect to the orbit measurement at optics correction which will be done at low current.

Displacement censor

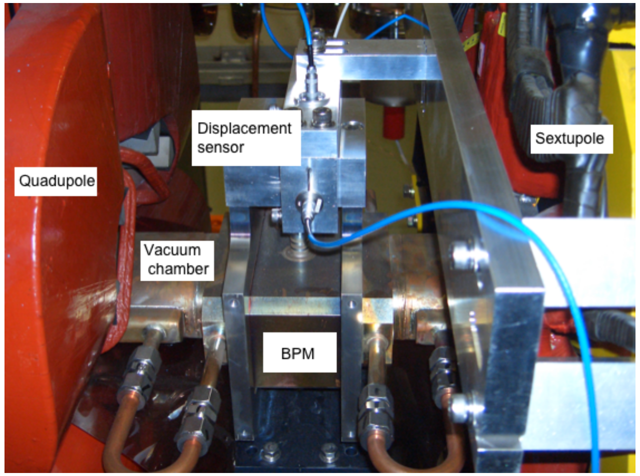
Specifications	
method	electrostatic (capacitive)
channels	2
range (mm)	0.5 - 2.5
resolution (µm)	< 0.2
nonlinearity (%)	< ±0.3
frequency response (Hz)	0 - 100
temperature coefficient (µm/deg.)	< 0.2

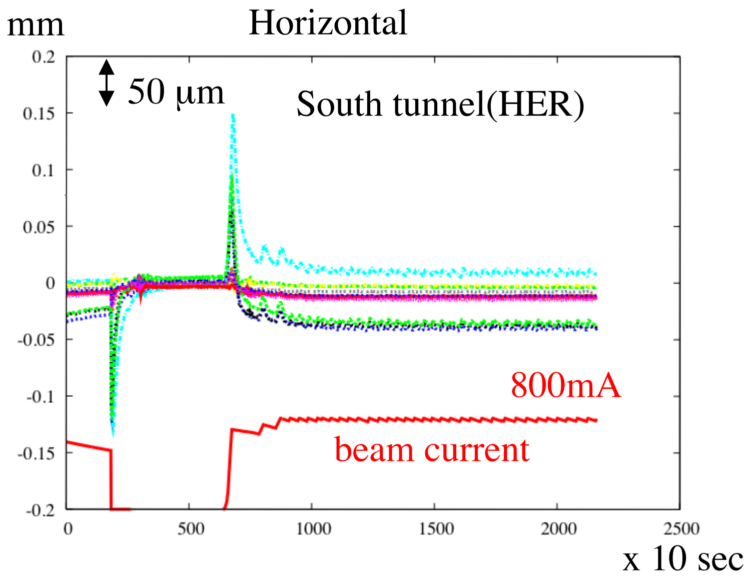


Gap detector developed at KEK.



•The number of censors to be installed and required bandwidth are not determined yet.





Example of movement of BPM with respect to a sextupole in KEKB

•Development of a new measurement target and arm

◊Measurement in KEKB showed that a big measurement error of about 10μm was caused by thermal expansion of an aluminum target.

◊We are developing a new target made of ceramics in order to reduce thermal deformation of the target and the arm of the sensors.

	Target	Arm
	ZPF – E04 (Zero Expansion Ceramic)	PSS – 50 (Metal Matrix Composite, SiC 50%, Si 50%)
Thermal expansion coefficient (1/K)	$0.4\ 10^{-6}$ (@20±3°C)	$2.8\ 10^{-6}$
Thermal conductivity (W/m/K)	8	175
Resistivity (Ohm·cm)	10^5	0.02
Density (g/cm^3)	2.6	2.8
	Non-magnetism	Non-magnetism

◊A problem is a cost (about 7,700$ / set).

The system can be used in critical place such as sextupoles for local chromaticity correction.

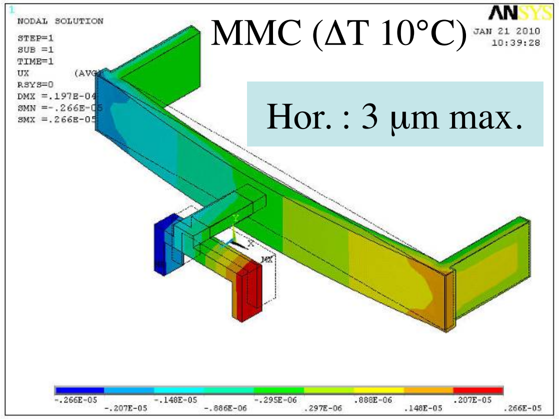
At local chromaticity correction sextupoles,

LER β_y=2700 m, K_2=1.47 m^{-2} ⇒ $\Delta\nu_y$=0.0003 for Δx = 1μm

HER β_y=2140 m, K_2=7.5 m^{-2} ⇒ $\Delta\nu_y$=0.0013 for Δx = 1μm

◊A set of the target and the arm is being fabricated.
The system will be tested in this spring run.

Estimated deformation (ANSYS simulation)



3. Bunch by bunch feedback system

Features of feedback system in SuperKEKB

- Longitudinal feedback system will be required.
- Noise in transverse feedback system should be minimized to reduce the blowup of the beam size during collision.
- Vacuum components such as kickers, power cables, feedthroughs and BPM electrodes should withstand large beam current.

A. Transverse feedback system

Requirement for damping time

Beam current of 3.6/2.6 A for LER/HER is assumed.

•Coupled bunch instability (CBI) growth time

1) RF cavity

	LER	HER
ARES (HOM)	9 ms	58 ms
Super (HOM)	---	14 ms

2) Resistive wall

LER (Cu)	LER (Al)	HER (Cu)
3.6 ms	2.8 ms	3.1 ms

(Transverse radiation damping time : LER 37.4 ms, HER 56.4 ms)

3) Electron cloud instability (ECI) in LER

0.5ms at the average/central electron density of 5 10^{10}/1.1 10^{11} m^{-3} in drift space without solenoid field (Y. Susaki at LER2010). The growth time will be increased if solenoids reduce the electron density.

4) Fast ion instability (FII) in HER

0.3 ms (shown later)

◊Required feedback damping time ⇨ LER : < 0.5 to 1ms (ECI)
HER : < 0.3 ms (FII)

◊If the growth time of ECI and FII is larger than that of present estimation, required damping time for the feedback is relaxed to about 1 ms.

◊The growth time of ECI and FII should be studied more.

•Fast ion instability (FII)

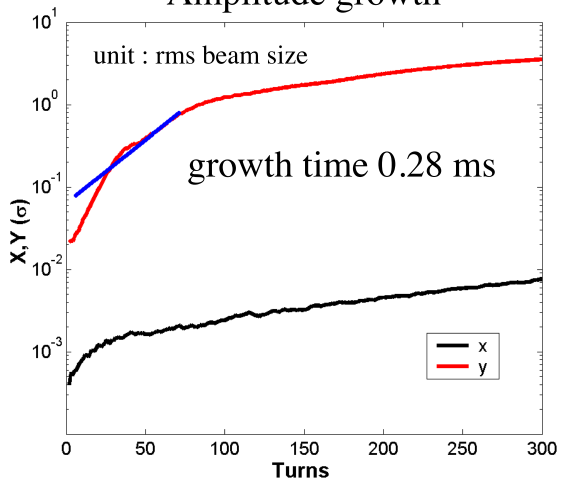
◊A simulation study just started with a tentative lattice parameters with a code by L . Wang.

◊A very preliminary result is given here as an example.

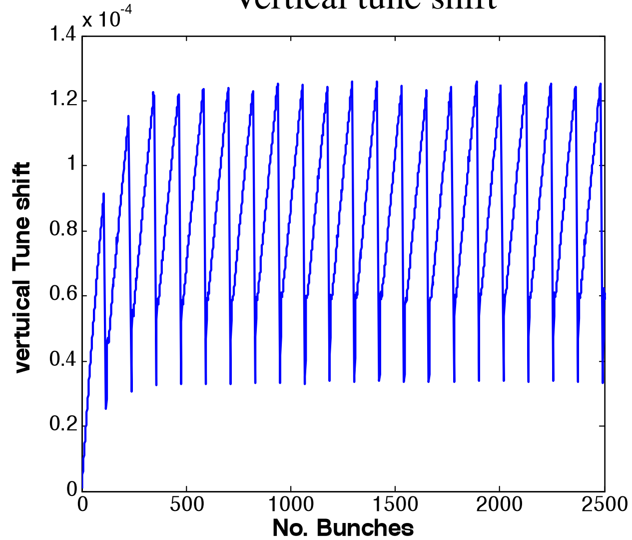
Parameters for a simulation

# of bunches / train	100
Bunch separation	2 RF buckets
Train gap	20 RF buckets
# of trains	21
Pressure	1 nTorr
Ion	CO+
Coupling	0.2 %

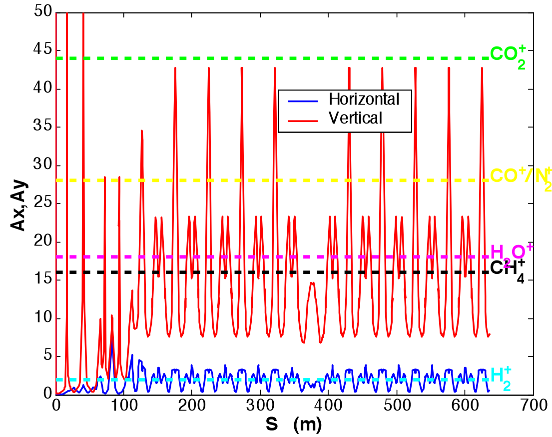
Amplitude growth



Vertical tune shift



Critical mass



◊Vertical amplitude grows 10 % of the beam size after 25 turns.

◊Vertical tune shift by ions is 1.2×10^{-4} .

◊Critical mass is larger than mass of CO at some places in the ring.

◊Is FII not so strong in very low emittance lattice ?

◊We need more study including a bunch by bunch feedback.

Calculation by L. Wang

System

1) BPM

◊Good time and frequency response.

2) Low noise front-end electronics

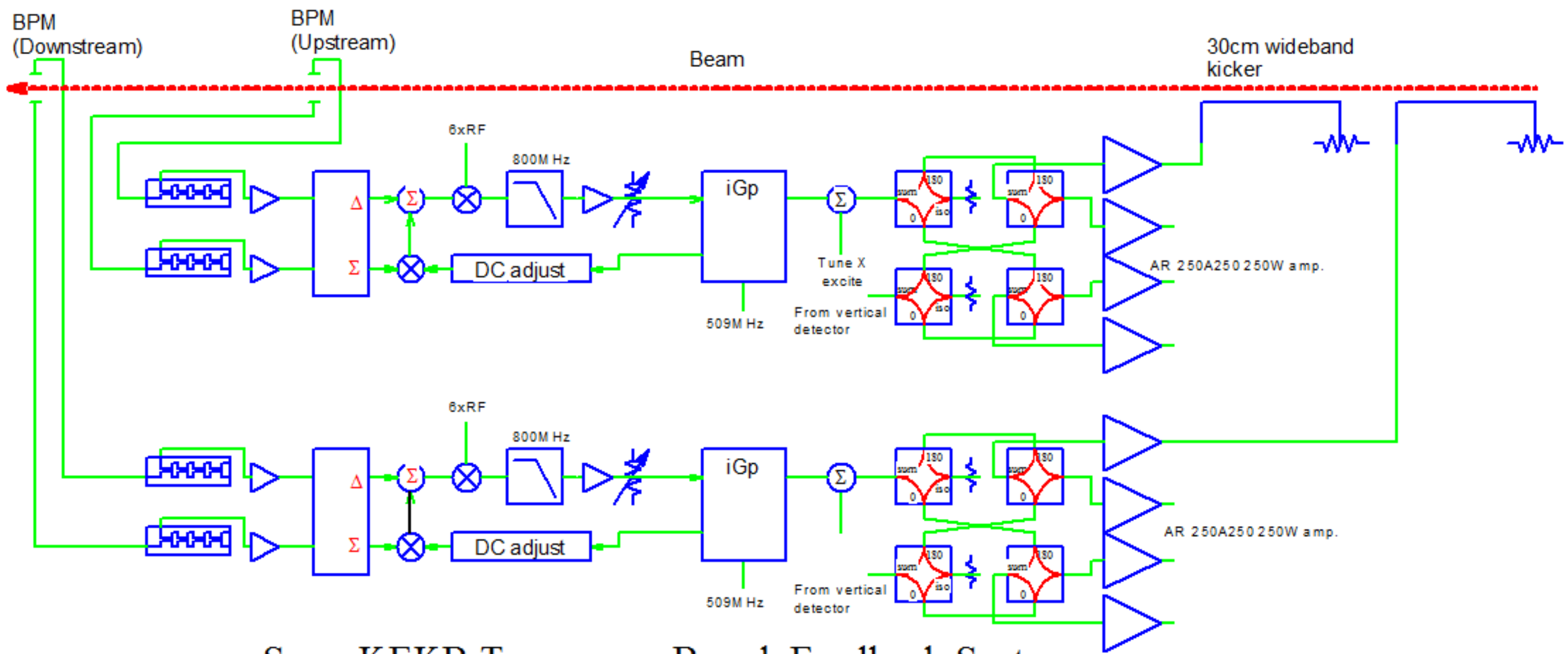
3)Digital filter using iGp

4)Power amp

◊Total 16 amps with 500 W output.

5) Kicker

◊Two sets of a short stripline kicker per ring which correspond to two feedback loops with 90 deg phase difference.



SuperKEKB Transverse Bunch Feedback System

iGp digital signal processing system

•Features

◊Developed under US-Japan collaboration (KEK-SLAC). Firmware is supplied by DimTel.

◊Adaptable to almost any harmonic number.

◊Operation at 509MHz is possible for KEKB.

◊8tap FIR(KEKB) to 32 Tap FIR (DAFNE) are available.

◊Down sampling function for Longitudinal feedback.

◊Bunch-selected FB ON/OFF and excitation.

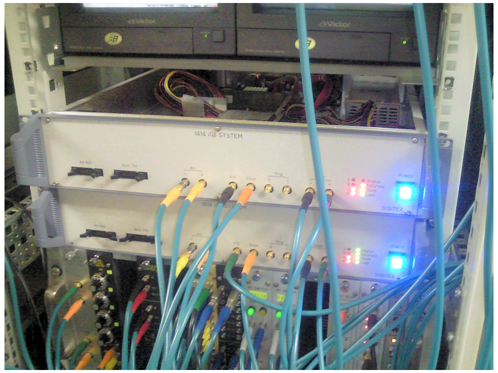
◊Transient-domain analysis for study of instability.

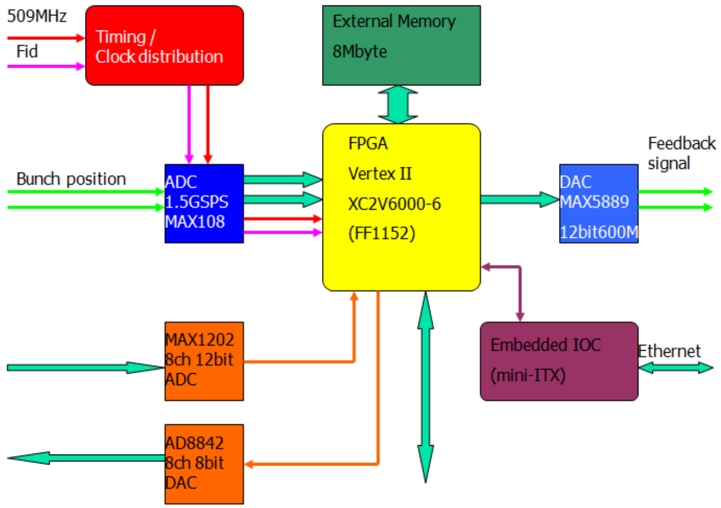
◊Capable to monitor a feedback signal without disturbing feedback.

•Status in KEKB

◊Tested successfully for the transverse and longitudinal system. Now planning replacement of existing 2 tap filters to iGps.

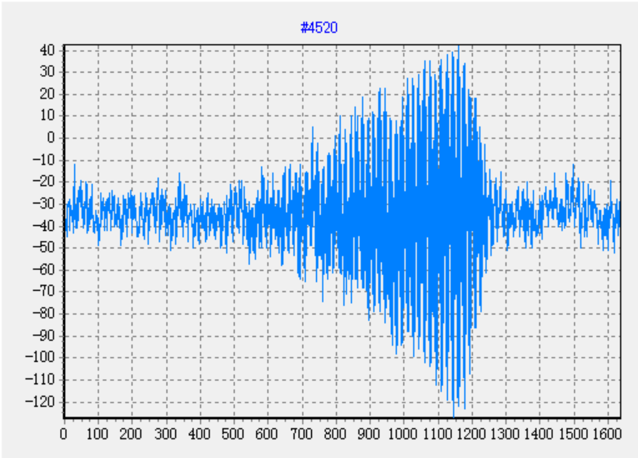
•Next generation system with a digital filter working at ~1.3 GHz using new FPGA, and ADC and DAC with higher resolution is under development.





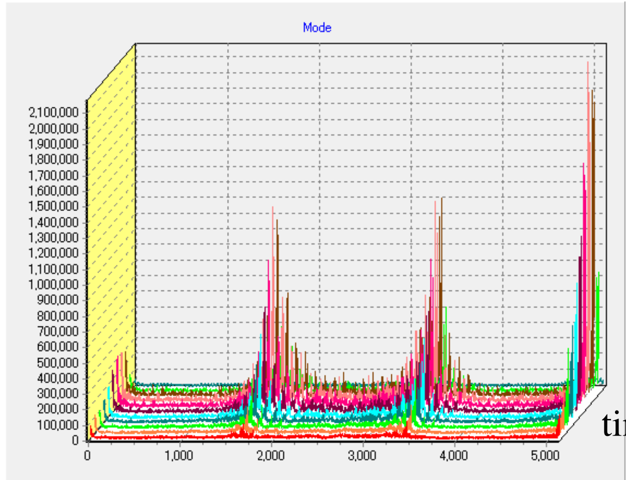
•Example of transient-domain analysis with iGp at KEKB HER

Amplitude growth of a bunch



turn

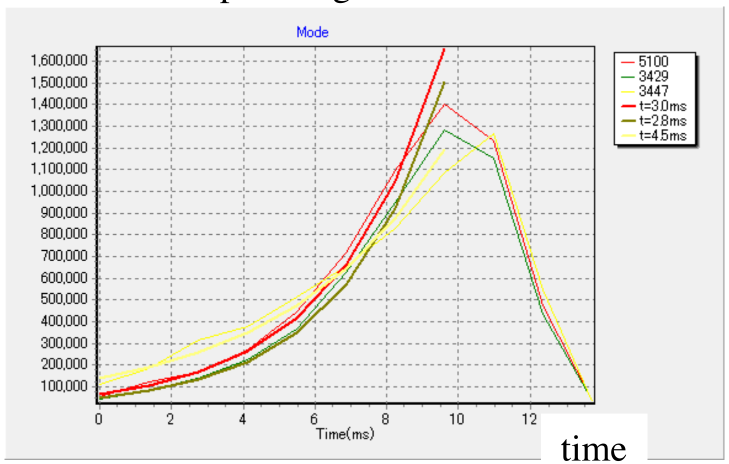
FFT



time

mode no.

Amplitude growth of modes



time

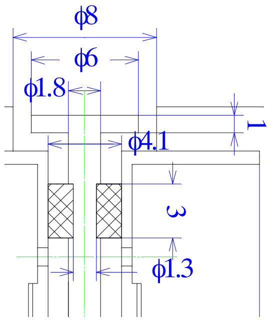
◊FB turned off during 12 ms, then turned on again.
◊Data of 1600turns of all the bunches were taken in this sequence, then FFT was applied to get oscillation modes.

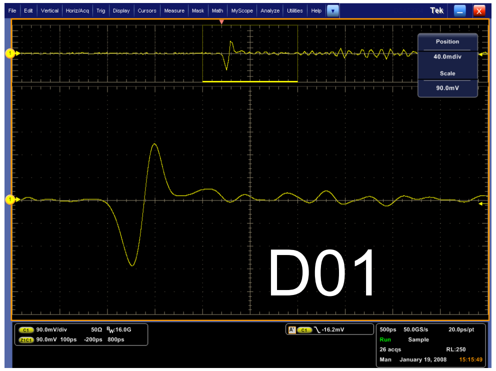
◊The result shows that

dominant mode of the coupled bunch instability is 5110, damping time of FB system is around 0.8ms at 800mA.

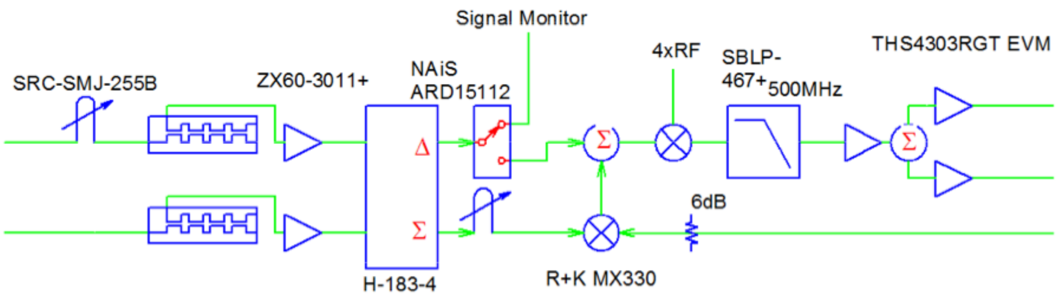
Development of Button electrodes and Lower noise front-end

•A feedthrough with low ε_r(~ 4) sealing is under development to get good time and frequency response.





•Lower noise front-end for the transverse feedback system is under development.



◊A new detector is being tested by a beam simulator with repetition of 127 MHz using step recovery diodes.

◊An experiment measuring the effect of the feedback gain on the luminosity is planned with a new detector and the iGp which replaces the existing two tap filter.

Transverse kicker

•Two sets of a short stripline kicker per ring

R_{sh}=10kΩ per kicker, amp of 500W, 2 kickers -> V_{kicker}=8.9 kV

⇨ Max. damping time 0.27ms(LER), 0.45ms (HER) for max amplitude of 0.3mm.

•Similar design with a present kicker

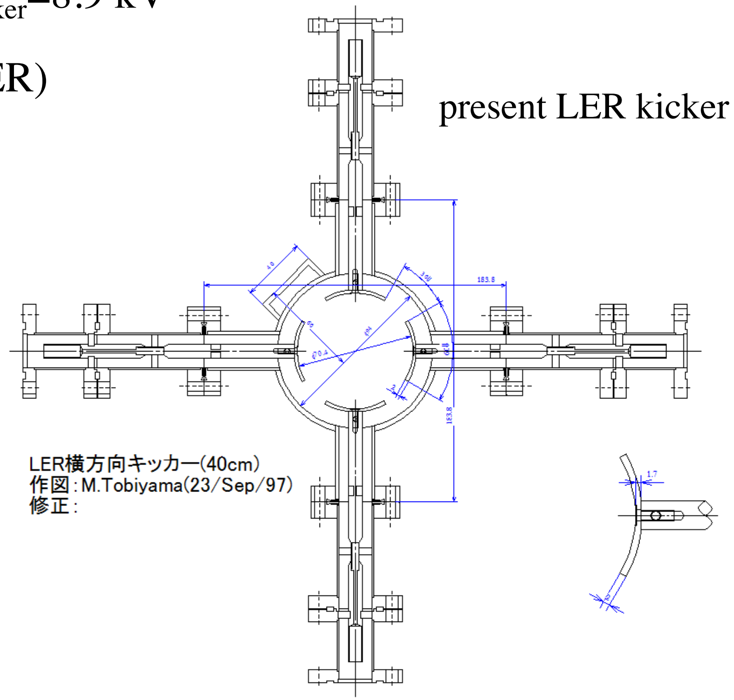
◊Improved support structure for electrodes

A structure where electrodes are placed at same level as chamber surface is being considered.

The system needs consideration on trapped mode.

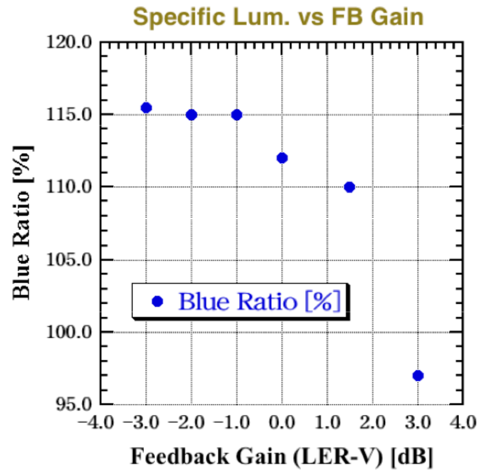
◊Cooling of the electrodes will be fairly difficult.

present LER kicker

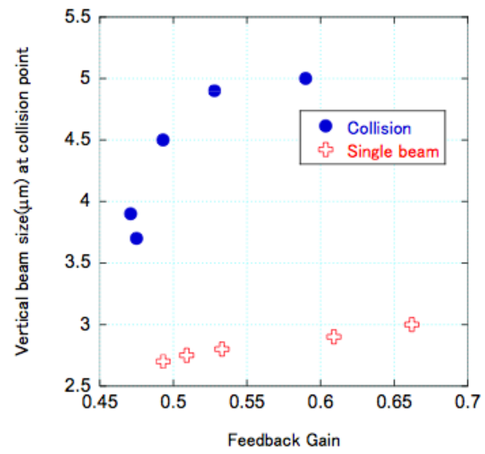


Effect of feedback noise on the luminosity

- Higher vertical feedback gain in LER degraded the luminosity in KEKB operated without Crab cavities.
- A simulation by K. Ohmi showed that fast beam noise whose amplitude is 2 % of beam size degrades the luminosity by 20 %.
- An experiment was carried out in last December by applying sinusoidal vertical kick to the beam by the feedback kicker.



- The result showed that,
  - ◊The luminosity was degraded by the excitation of 0.2 σ_y, while a simulation showed that it was degraded by the excitation of 0.05 σ_y . The luminosity seems not so sensitive that the simulation predicts.
  - ◊The beam could be excited by the kick with frequency far from a betatron tune so large that the luminosity is affected.



- The measurement showed that the feedback noise should be reduced as small as possible.

B. Longitudinal feedback system

Requirement for the damping time

Beam current of 3.6/2.6A for LER/HER is assumed.

•CBI growth time by cavity impedance

	LER	HER
ARES (HOM)	15 ms	75 ms
ARES (0-π mode)	29 ms	--
Super (HOM)	---	58 ms

(Longitudinal radiation damping time : LER 18.7 ms, HER 28.2 ms)

⇨ LER needs a feedback system with damping time of about 10 ms.

Starting only with LER system might be better taking into account of cost.

System

1) BPM, frontend electronics, digital filter

◊Same as those of transverse system.

2) Power amp

◊Four 500 W amps per kicker

3) Kicker

◊ DAFNE type kickers with Q value of about 5: two kickers in a ring

◊R_{sh}=650Ω/kicker, amp. 500W x 4 / kicker, two kickers -> V_{kicker}=3.2kV

⇨ Max. damping time is 10ms if (ΔE/E)max. =4×10^{-4} (LER).

◊Start with two kickers system (reserving a space for additional two kickers).

◊Re-design with a better 3D code.

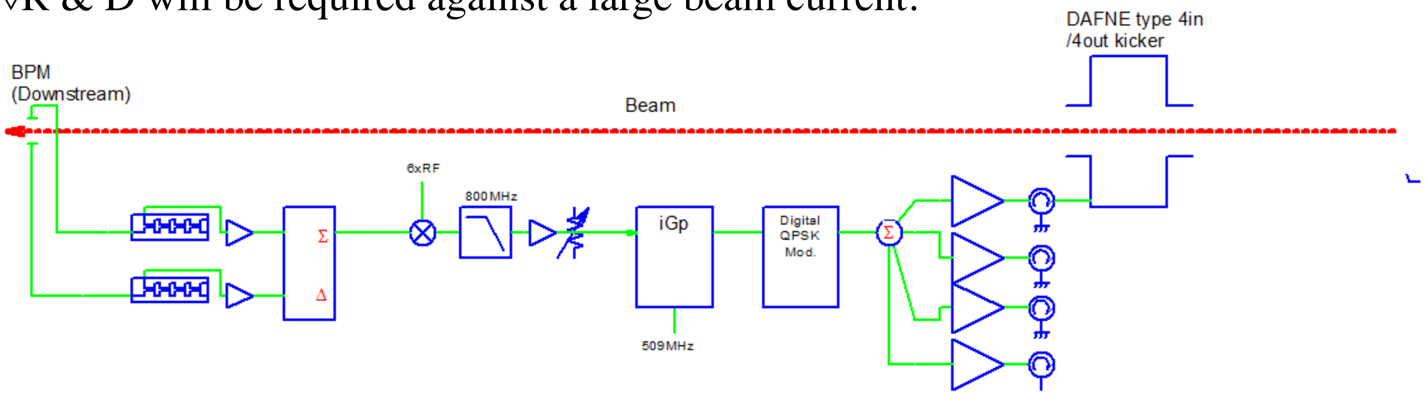
◊Improve cooling structure of a body.

4) Power cable and feedthrough

◊R & D will be required against a large beam current.

5) Back-end electronics

A digital QPSK modulator from the idea of Dr. John Fox (SLAC) is tested.

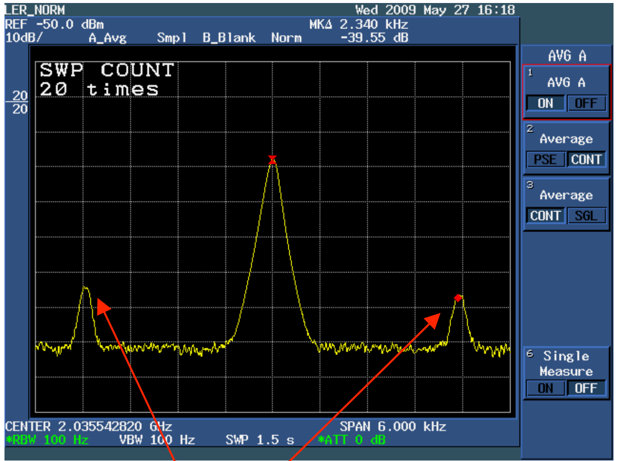


SuperKEKB Longitudinal Bunch Feedback System

A beam test of longitudinal feedback system

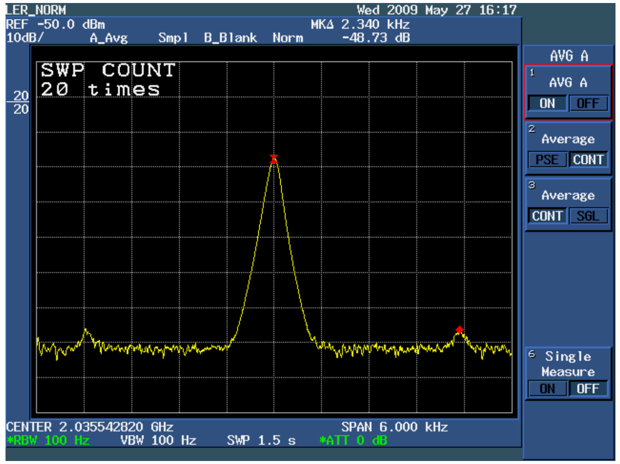
Grow(Excite)/Damp experiment

Excite

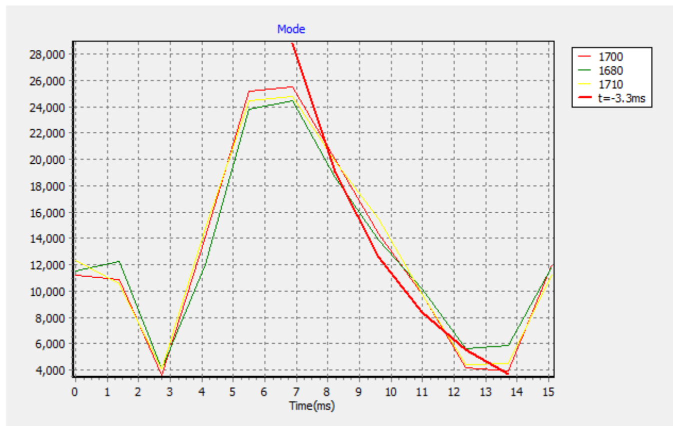


synchrotron sidebands

Damp



Amplitude of modes



Damping time ~3 to 6 ms

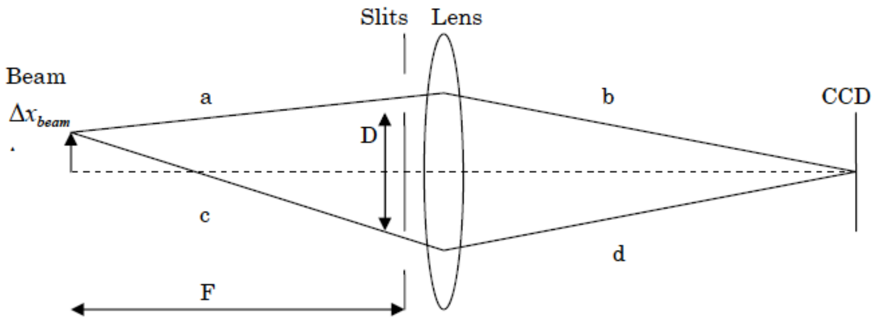
4. Synchrotron light monitor

A. Visible light monitor

Interferometers

SR Source Bend Parameter	S-LER1 (BSWFRP)	S-HER (BSWOLE)	Units
ε_x	2.70E-09	2.30E-09	m
κ	0.40%	0.35%	
ε_y	1.08E-11	8.05E-12	m
β_y	30.09	48.71	m
σ_y	18.0	19.8	μm
Beam Energy	4	7	GeV
Bend effective length	0.86	2.90	m
Bend angle	5.04	3.86	mrad
Bend radius ρ	171.3	751.2	m
Observation wavelength λ	4.00E-07	4.00E-07	m
SR Opening angle θ_c (λ)	1.0	0.6	mrad
Slits opening angle D/F	1.2	1.2	mrad
Max. Visibility (fringe depth) γ_{max}	95%	95%	
Min. measurable beam size $\sigma_{y\ min}$	17.0	17.0	μm

- Resolution fundamentally limited by measurement wavelength and opening angle between slits from beam (D/F).
- Max. slit separation determined by beam spread and mechanical considerations.



- Beam size measurement is possible with interferometers, though is at the limit of the interferometer resolution.
- Measurement wavelength needs to be lowered to fit beam size into dynamic range.
- Limitation on slit separation is due to antechamber height (14 mm).
  - ◊Extraction mirror will be in antechamber for reduced impedance.
  - ◊If we could increase antechamber height by factor of two for 2 m (LER) or 4 m (HER) in front of extraction mirror, we could correspondingly reduce minimum measurable beam size by factor of two. Appears difficult due to presence of upstream quads.

<u>Visible light options</u>

•Standard interferometer using σ polarization

•Rotate polarizer -> interferometer using π polarization

◊All wavelengths come to minimum at center, so can use broader spectrum.

•Rotate polarizer, remove slits
-> Vertical polarization monitor (proposed at PSI)

◊Resolution similar to interferometer with slits set at π polarization peaks.

Not as good theoretical resolution as interferometer (which can push slit separations out into tails of light distribution).

◊Greater open aperture than vertical polarization interferometer

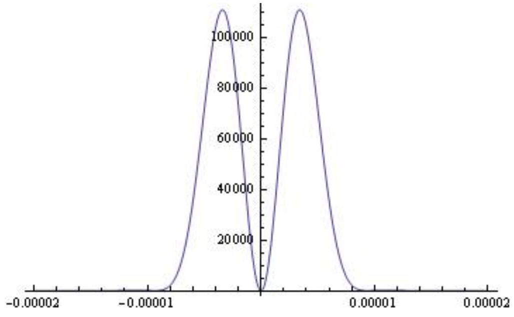
◊More complicated beam current dependence due to heat-induced mirror distortions

Must understand and correct for distortion of whole mirror rather than just two small regions.

•All above options under consideration for applicability for different types of measurements

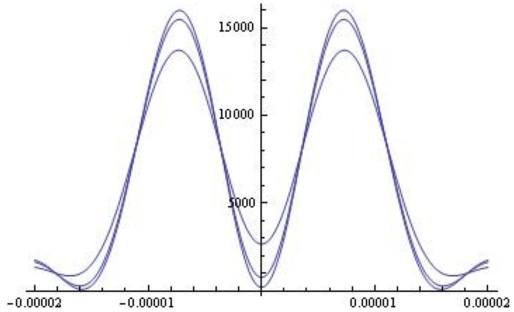
•Longitudinal measurements: streak camera

Point Spread Function of π polarization light in LER



Convolved image of vertical polarization monitor

LER : σ=20,40,80[μm]



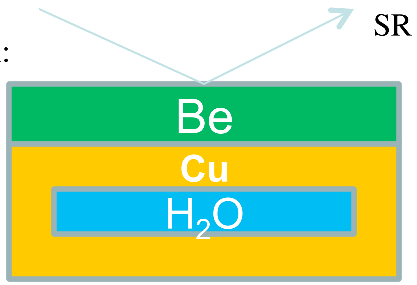
Extraction Mirror

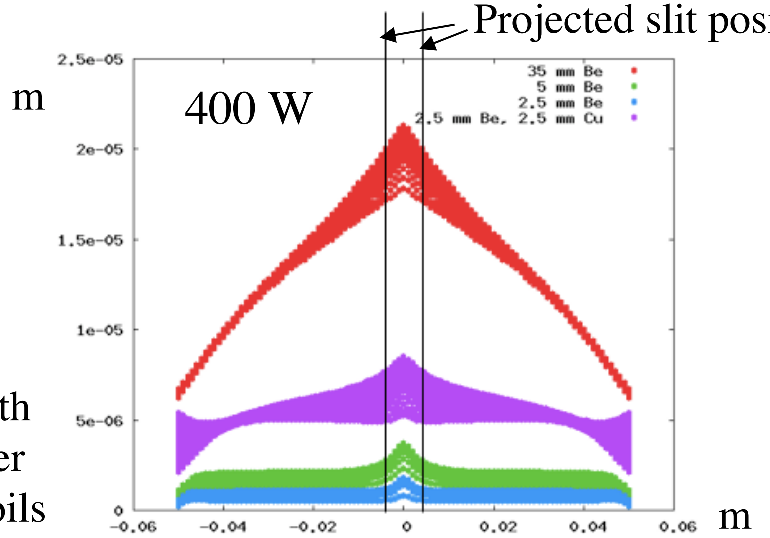
•Heat load at high beam currents causes mirror distortions.
•Increase in power load with nano-beam option is much less severe than with high-current option. LER bend radius doubled.

	LER (SuperKEKB)	LER (KEKB)	HER (SuperKEKB)	HER (KEKB)
Energy(GeV)	**4**	**3.5**	**7**	**8**
Current(A)	**3.6**	**2**	**2.6**	**1.4**
Bending radius(m)	**171.3**	**85.7**	**751.2**	**580**
Power(W/mrad)	**74**	**48**	**115**	**136**
Total incident power(W)	**186**	**121**	**287**	**248**

•Investigating new mirror structures, e.g., thin Be on thin water-cooled Cu plate.

Cross –section:





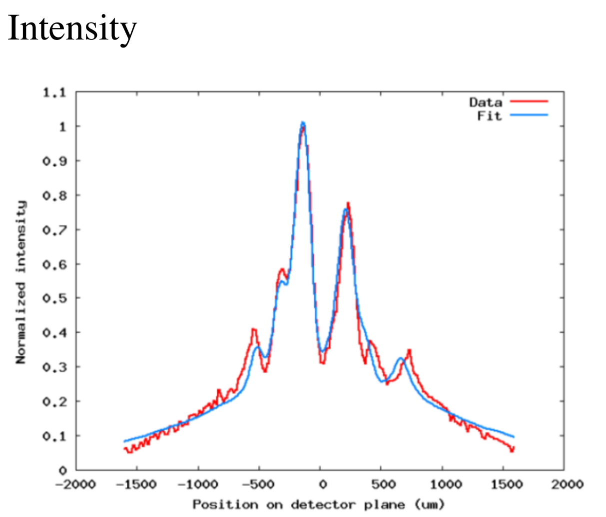
•Simulation showed that deformation decreases with thin (2.5 mm) Be mirror, but laminar cooling water flow will be needed in back rather than parallel coils as used at present, to avoid surface distortions.

•We plan to make a mirror of this type to test.

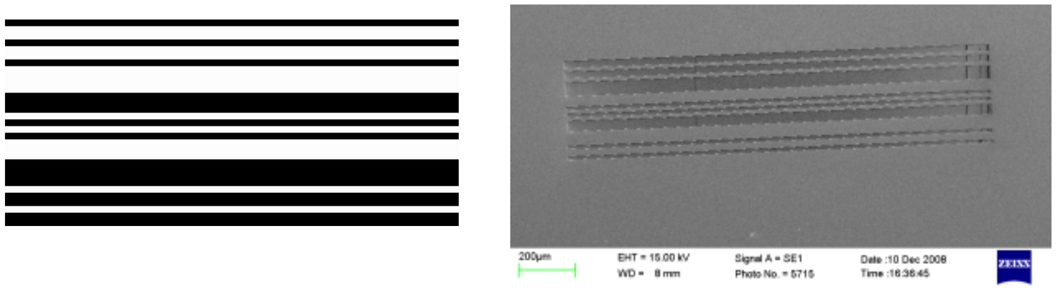
B. X-ray Beam Size Monitors

- Purpose is to provide high-resolution bunch-by-bunch measurement capability, with low beam current dependence (low distortion).

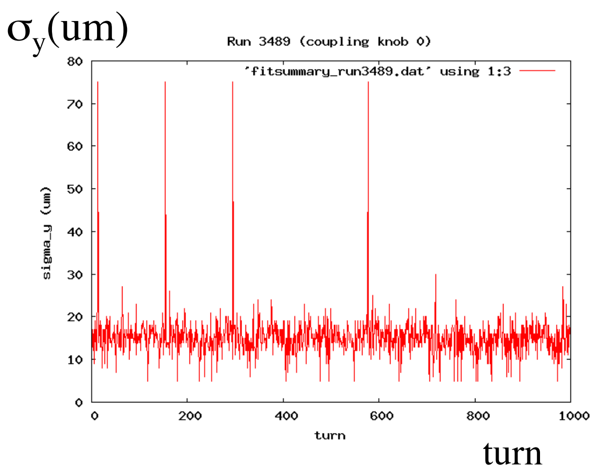
- Developing system based on Coded Aperture Imaging.
  - ◊Technique developed by X-ray astronomers using a mask to modulate incoming light.
  - ◊Resulting image must be deconvolved through mask response (including diffraction and spectral width) to reconstruct object.
  - ◊Open aperture of 50% gives high flux throughput for bunch-by-bunch measurements. Heat-sensitive monochromator not needed.



Detector signal measured at CesrTA. Beam size ~16 μm.



Uniformly Redundant Array (URA) for x-ray imaging being tested at CesrTA



Turn-by-turn single-bunch measurements at CesrTA

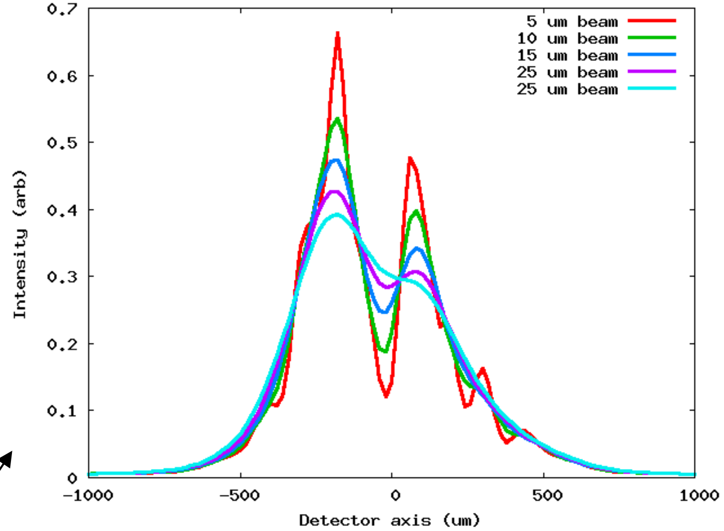
X-ray Source

Xray Source Bend Par.	S-LER (BS2FRP)	S-HER (BS2OLE)	Units
ε_x	2.70E-09	2.30E-09	m
κ	0.40%	0.35%	
ε_y	1.08E-11	8.05E-12	m
β_y	46.9	22.9	m
σ_y	22.5	13.6	µm
Beam Energy	4	7	GeV
Effective length	0.89	3.8	m
Bend angle	56.1	44.5	mrad
ρ	15.9	85.4	m
Critical Energy	8.9	8.8	keV

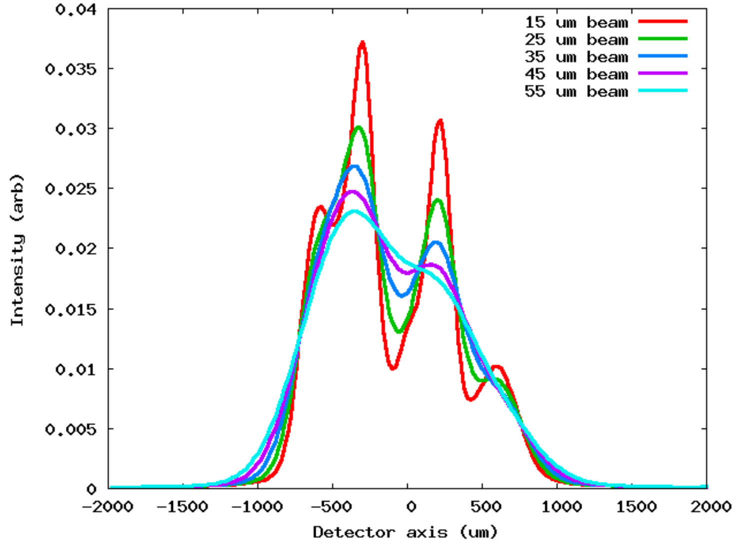
- Use last arc bend before straight section (LER: Fuji, HER: Oho)
- Simulation with 5(10) µm pitch coded aperture in HER(LER) shows required beam size resolution is achievable.

Simulated detector response for different beam sizes.

Beam to mask: 6 m, Mask to detector: 24 m



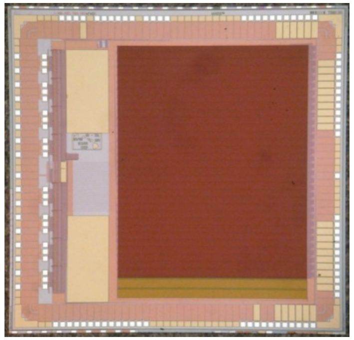
HER: 5 µm pitch coded aperture



LER: 10 µm pitch coded aperture

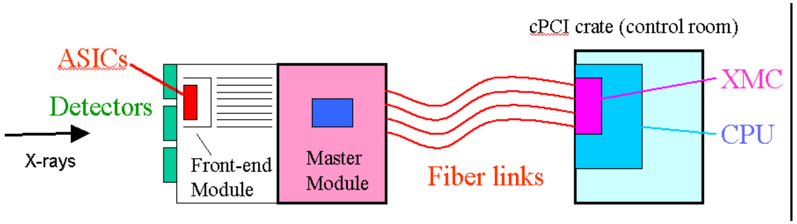
R & D of X-ray Beam Size Monitors

- Collaboration with Cornell (CesrTA ILC damping ring study machine group) and U. Hawaii (Belle detector group)+SLAC.
- Beam size measurements down to 15-20 μm demonstrated so far. Looks promising for SuperKEKB.
- Fermionics InGaAs detector tested at Cornell and KEK PF. Time resolution sufficient for bunch-by-bunch measurements, but efficiency low at high critical energies. Investigating further detector options (KEK/UH/SLAC).
- STURM (Sampler of Transients for Uniformly Reduntant Mask) readout ASIC designed at U. Hawaii.

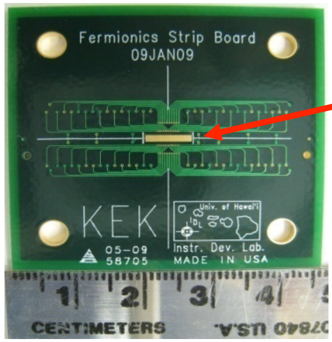


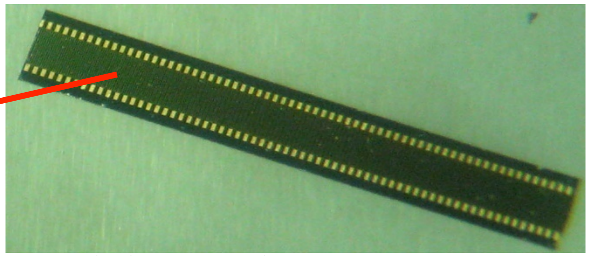
STURM ASIC for high-speed readout (G. Varner).
Ver. 1 tested at KEK PF in March 2009.
Ver. 2 in fabrication now. Ver. 2 specs:

8	channels/STURM sampling
1	monitor channel
4	TSA sample buffers
8	samples/TSA buffer (32x channel)
288	Wilkinson conversion cells
1-200	GSa/s effective (5ps - 1ns Tstep)
1	word (RAM) sample readout
1+n*0.02	us to read n samples
100	kHz sustained readout (orbit)



Signal flow diagram for x-ray monitor system





Fermionics InGaAs detector array.
Also being used at CesrTA (with Cornell-developed mount and readout).

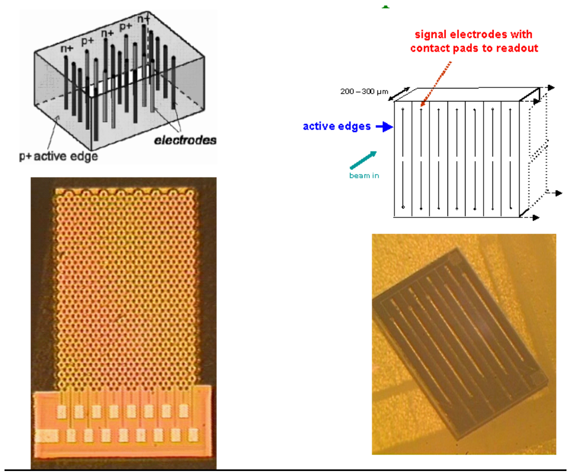
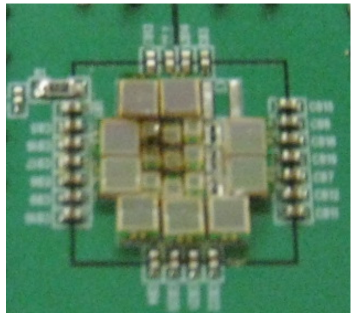


Illustration of two of the detector concepts to be explored in next phase of x-ray detector development. At left, a regular pattern of n and p electrodes, at right, a trench structure, which provides a more uniform drift volume.



Hamamatsu MPPC test array: high gain ("silicon PMT"), but low resolution: candidate for slow x-ray monitor.

Direct-detection X-ray monitor

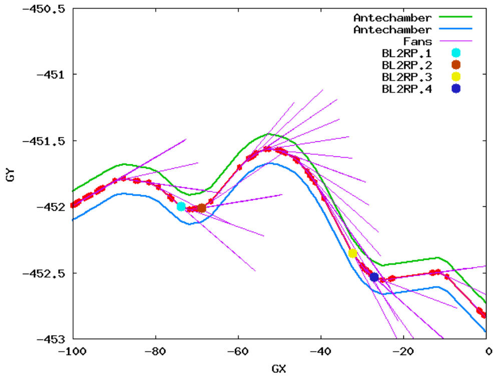
- Basic principle is to use X-rays penetrating chamber walls downstream of bends directly to measure beam emittance (very old-fashioned method).
- System is simple. No optics elements are required. It requires small thin region (~1 mm) on antechamber outer wall to extract X-ray.

  Consulting with vacuum group
  – cooling an issue, but may be possible.
- Some potential candidate locations are in local chromaticity correction sections around IP with huge beta functions and no overlap (final evaluation pending lattice finalization).

SR Source Bend Parameters

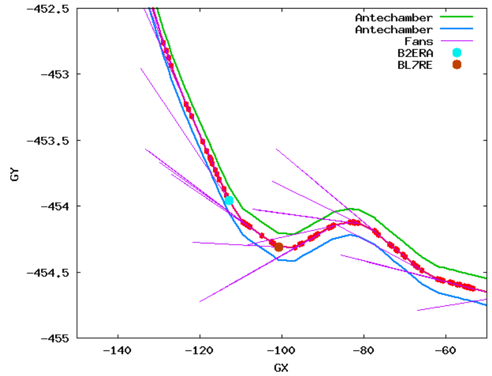
	LER BL2LP	LER BL2RP	HER B2ERA	HER BL7RE
βy (m)	1200.00	1000.00	418.00	458.70
σy (μm)	123.94	113.14	59.61	62.44
σ'y (mrad)	0.10	0.11	0.14	0.14
Spot size (μm)	145.62	137.16	98.52	102.96
Change in spot size for doubling of beam size	1.78	1.74	1.45	1.45

SR Fans: LER right side of IR



BL2RP.1: ×
BL2RP.2: ○ ?
BL2RP.3: ×
BL2RP.4: ○?

SR Fans: HER right side of IR



B2ERA: △
BL7RE: ○ ?

C. Beamstrahlung Monitor

- Developed by G. Bonvicini (Belle, Wayne State U.) originally for use at CESR.
- Uses relative strengths of x- and y-polarization of wide-angle beamstrahlung to diagnose quality, e.g. beam separation and beam size of collision.
- Estimation of signal and background level has just started with a simulation code.
- Standardized, compact light spectrometers to be implemented at each viewport, with 0.2 mrad angular resolution, and 8 PMTs (2 polarizations, 4 wavelengths).
- Device has background discrimination rejection through simultaneous detection of 4 different wavelengths.

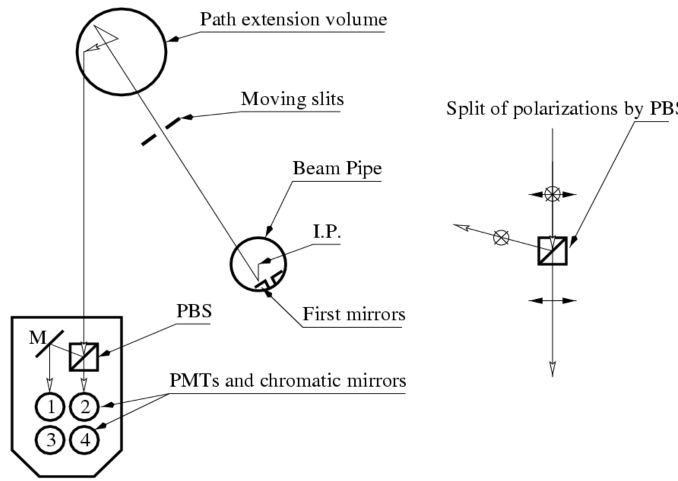
Most important change: much stronger beams at KEKB.
Comparison at θ=5mrad, λ=300-600nm, 0.5mrad^2 acceptance)

	CESR-c	SuperKEKB	Ratio
Sx (Hz)	6E4	3E11(L),1E11(H) (Prel.)	2-6E6
Sy(Hz)	6E4	6E10(L),2E10(H) (Prel.)	0.3-1E6
Bx(Hz)($\propto$N/γ)	2E6 (est.)	2E5(L),1E5(H)	0.05-0.1
By(Hz)($\propto$N/γ)	2E6 (est.)	2E6(L),1E6(H)	0.5-1
B(from beam)	Very small	Very small	

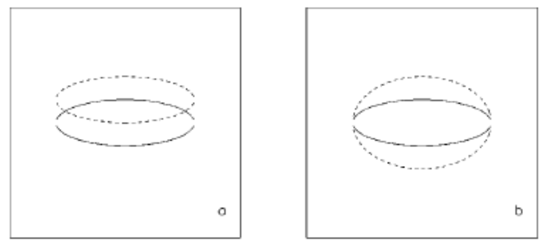
S : Signal, B : Background

By G. Bonvicini

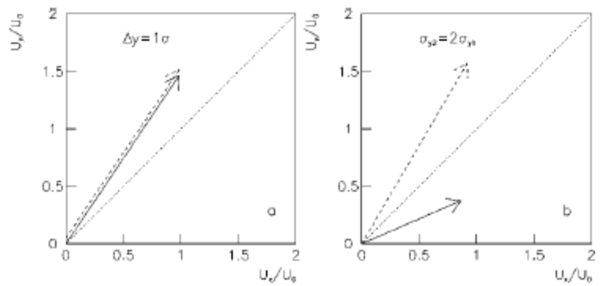
Transverse view



Two beams at IP



Polarization



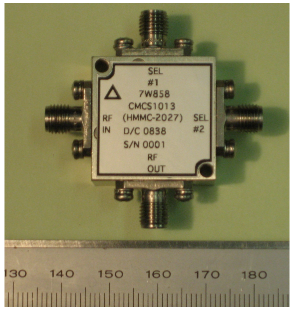
G. Bonvicini et al., Phys. Rev. E 59, 4584 (1999)

5. Gated Measurement for Bunch-Tune, -Orbit and -Phase

Development of a fast gate module

- A fast gate module is developed for a fast gate to measure the tune, orbit and longitudinal phase of each bunch separated by 2ns.

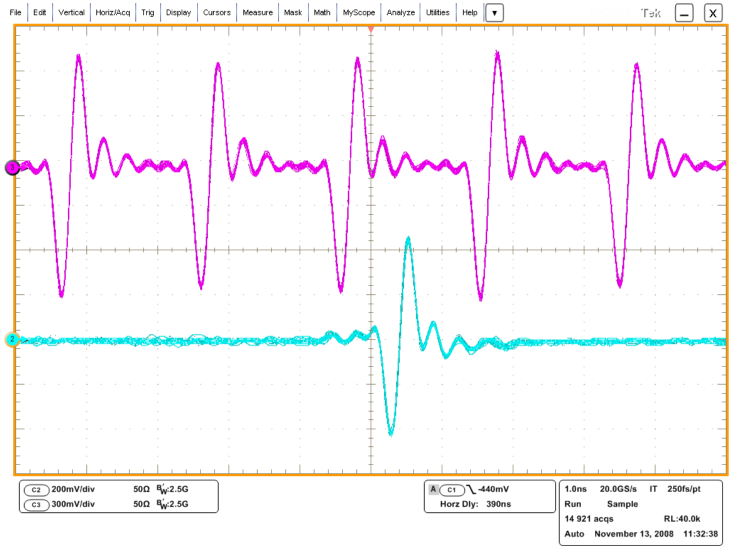
Agilent HMMC-2027



Specifications

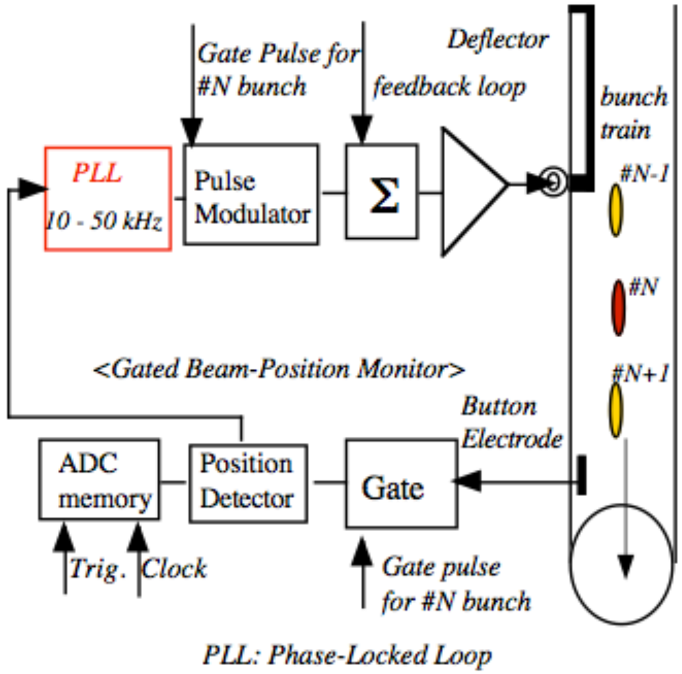
Input/Output Impedance	50 Ω
Input Power	> +20 dBm
Bandwidth	1.0 MHz - 5.0 GHz
Switching Time	200 ps
ON/OFF Isolation	> 50 dB @2GHz
Insertion Loss	< 10 dB@2GHz
Control	0 - - 0.8 V

Beam test

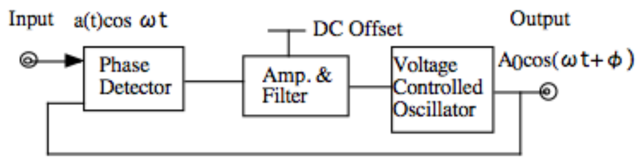


1 ns/div

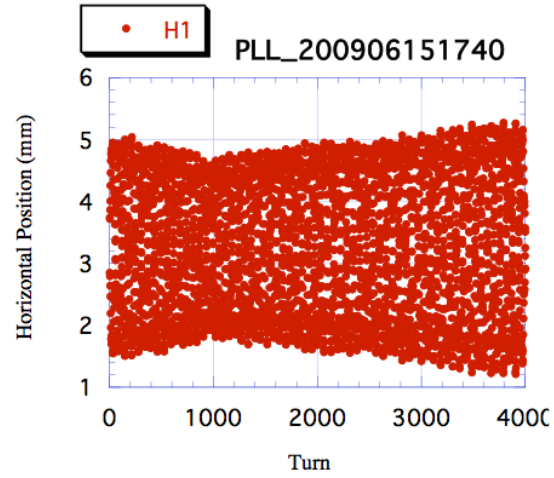
Excitation of a pilot bunch by PLL



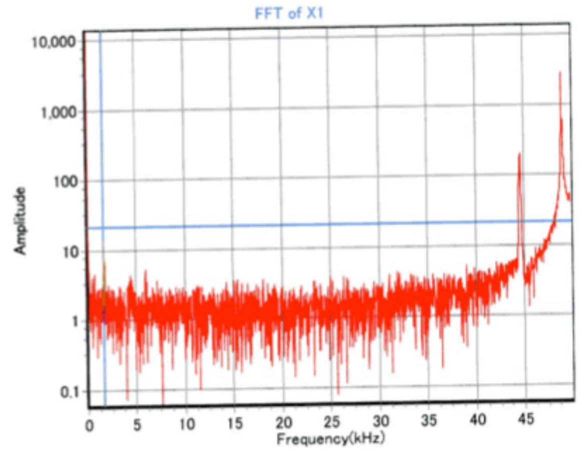
PLL



Excited amplitude of a bunch



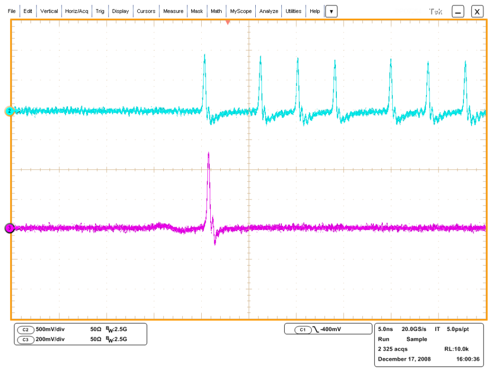
FFT of the oscillation



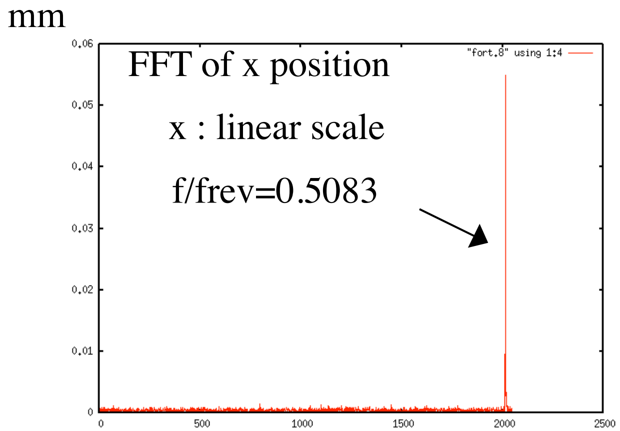
A betatron oscillation of a pilot bunch was successfully excited by PLL.

Gated Measurement of a pilot bunch

- A gate circuit was tested by beam to pickup a signal of a pilot bunch located 6ns after a bunch train.



gated signal



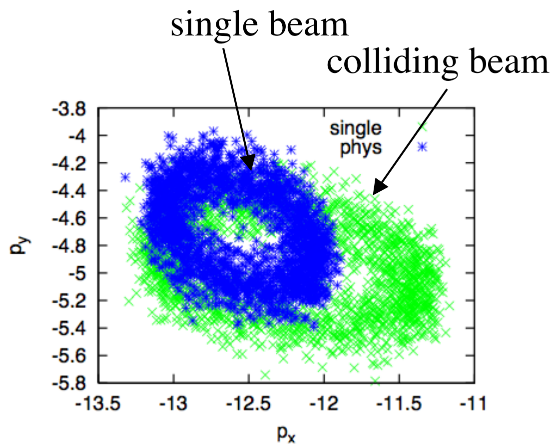
FFT of a gated signal measured by a turn by turn BPM

- X-Y coupling was measured by eight-electrodes-BPMs with a gate module during physics run.

◊The pilot bunch was kicked by the PLL exciter, then its turn-by-turn position was measured with the gate module. Detection modules were log-ratio circuits supplied by Bergoz.

◊The experiment showed that the system had a sensitivity to measure R parameters.

◊A fast switch of a specific channel in the gate module was damaged twice during measurement. The cause is being investigated. The experiment is planned in next run with improved calibration of the system and the repaired gate module.



by K. Ohmi

6. Summary

1)Beam position monitor

- Standard BPM
  - ◊Prototype of the button electrode was successfully tested with beam.
  - ◊Two detection circuits, namely the narrowband detector and the medium-band detector, are under development.
  - ◊Selection of two detectors is not done yet. Both detectors may be used together to reduce a cost.
- BPM for collision feedback
  - ◊A prototype of the button electrode and feedthrough has been ordered and will be tested in this spring.
  - ◊Development of the detection circuit has already started. The evaluation circuit will be tested in this spring.
- RF noise in RF straight section might be still a problem though the orbit error due to the noise is estimated to be a level of 0.7 μm at 100mA.
- If the requirement from optics which is not specified yet is much tighter than that of KEKB, the BPM system should be reconsidered. We need specification as soon as possible.

2) Bunch by bunch feedback system

- Common components to transverse and longitudinal system

  ◊The iGp digital filter will be used for whole system.

  ◊The low noise 3 GHz frontend electronics and BPM which has better time and frequency response are under development.

- Transverse feedback system

  ◊Two stripline kickers for each ring will be used.

  ◊ New stripline electrodes with improved support structure and good cooling is to be designed.

  ◊ Expected damping time is comparable to growth time based on present status of simulations of ECI and FII.

  The study of ECI and FII has just started. More study is needed to determine target values of the damping time.

- Longitudinal feedback system

  ◊Two DAFNE type kickers will be used in LER.

  ◊Power cables, connectors and feedthroughs against large beam current need to be developed.

3) Synchrotron light monitor

- Visible light monitor
  - ◊The interferometer and streak cameras will be used for measuring transverse size and longitudinal profile of the beam, respectively.
  - ◊Vertically polarized synchrotron light might be used to determine the vertical beam size.
- X-ray monitor
  - ◊Fast measurement of the transverse beam size by the coded aperture method is being developed and will be implemented in SuperKEKB.
- Beamstrahlung monitor
  - ◊The monitor has a capability to be a useful monitor to get information of beam collision.
  - ◊A way of installation and detailed simulation study will be carried out along with the progress of IR design.
- Items to be considered hereafter
  - ◊Design of the extraction chamber and a transfer line for the X-ray monitor
  - ◊Design of a vacuum chamber for extraction mirror
  - ◊Thermal deformation of extraction mirror for visible light

4) Gated measurement

- A fast gate capable to gate a bunch signal separated by 2 ns was successfully tested by beam.
- A beam test kicking a pilot bunch by PLL was successfully done.
- A beam test showed that the detection of oscillation of a pilot bunch with the gate module had a sensitivity to measure the X-Y coupling.

5) DCCT, CT and loss monitor

- Similar system as that of KEKB will be used.