Beam Diagnostics

The 18th KEKB Accelerator Review Committee

March 5th, 2013

KEKB Monitor Group

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Contents

Introduction

System	Quantity		
	HER	LER	DR
Beam position monitor (BPM)	466	445	84
Displacement sensor	100	100	
Transverse bunch by bunch feedback	1	1	1
Longitudinal bunch by bunch feedback		1	
Visible light monitor	1	1	1
X-ray light monitor	1	1	
Beamstrahlung monitor	1	1	
Gated measurement	1	1	
Tune monitor	1	1	
Loss Monitor	200		34
DCCT	1	1	1
Bunch current monitor	1	1	1

Beam Position Monitor System

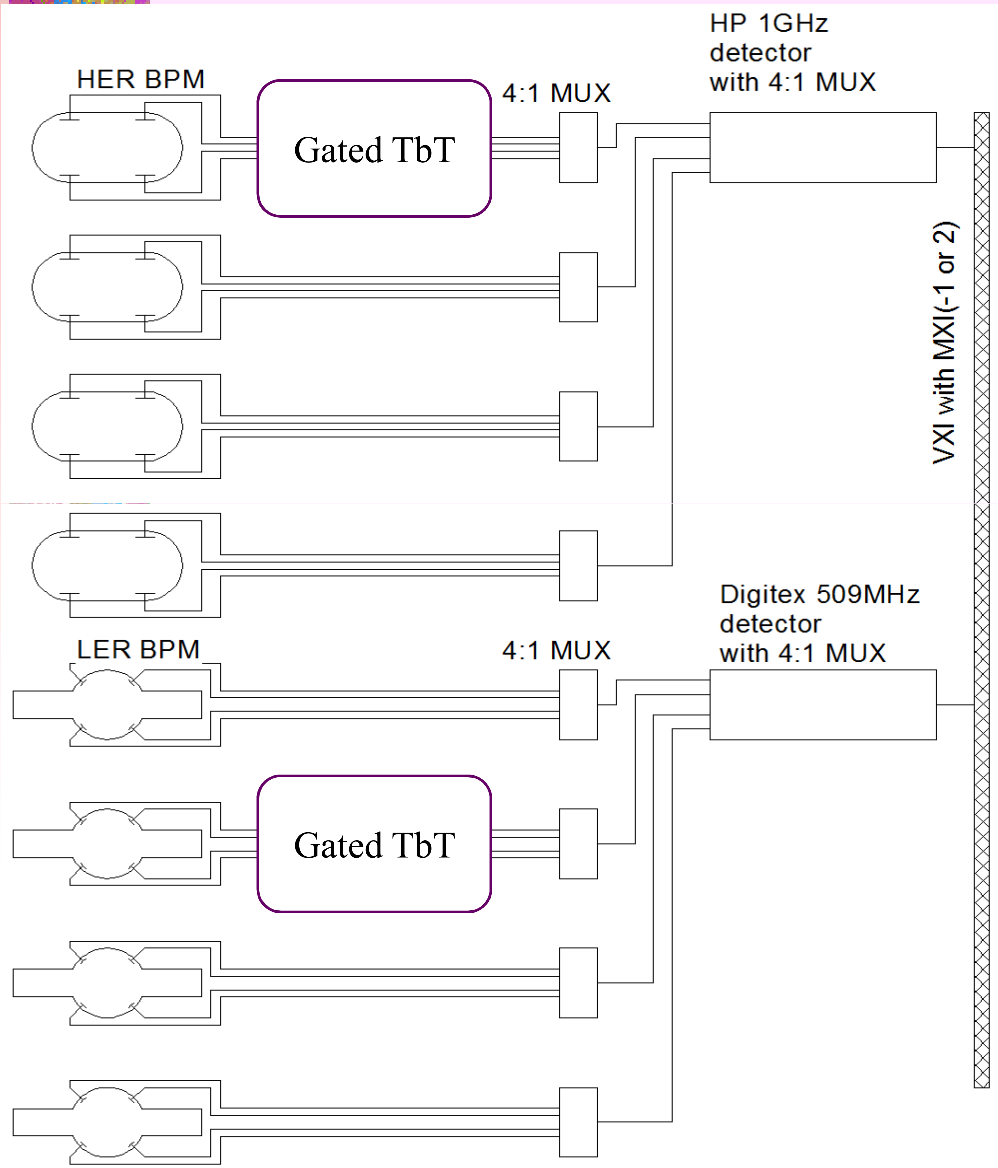
Beam Position Monitor System

Decisions made after last ARC

1. 70 turn-by-turn BPM detectors out of 270, 35 in each ring, will be installed for Phase 1.
   The detectors will be mainly used for injection tuning.
2. Four medium-band detectors will be installed for Phase 1.
   The detectors will be used for measuring orbit variation near local chromaticity correction sextupoles. No orbit feedback will be applied.
   HER : SLYTRE.1, SLYTRE.2
   LER : SLYTRP.1, SLYTRP.2
3. Four BPMs will be used for triggering the beam abort if a large horizontal orbit deviation is observed. The purpose of the monitors is to protect extraction windows for aborted beams.
4. A monitor measuring longitudinal position/phase of the injected bunch will be installed.

We are considering the use of commercial Libera based detectors for items 2, 3 and 4 above.

Configuration of main BPM system



- Super-heterodyne detectors in KEKB BPM system are also main detectors in SuperKEKB.
- Detection frequency in LER is lowered to 509 MHz due to the chamber cutoff frequency of 989 MHz.
- Selected 270 BPMs have *gated* turn-by-turn monitoring function.

BPM system at Phase 1

Type	Function	Resolution	Repetition	Number of units
Narrow-band of KEKB	Closed orbit correction, CCC, optics measurement	3μm	0.25Hz	109 (already have.)
New narrow-band with 509MHz detection	As above	2 to 3 μm	0.25Hz	133
Gated turn by turn	Injection tuning, optics measurement	50 - 100μm	100kHz	70
Medium-band	Measurement of orbit variation	< 2 to 3 μm	10kHz	4

One narrowband detector covers four BPMs.

IP feedback detectors might be tested though they are not needed at Phase 1.

Button electrode and BPM support for the LER

- Button electrode
  - Production of all electrodes is completed.
  - The electrodes are being installed on BPM blocks after coating with TiN.
    - Diameter : 6mm
    - Flange type for easy replacement and for removal during TiN coating of the chamber
    - Pin-type inner conductor for tight electrical connection..

- BPM block
  - All BPM blocks connected to LER arc chambers have been made by the vacuum group.

Button electrode

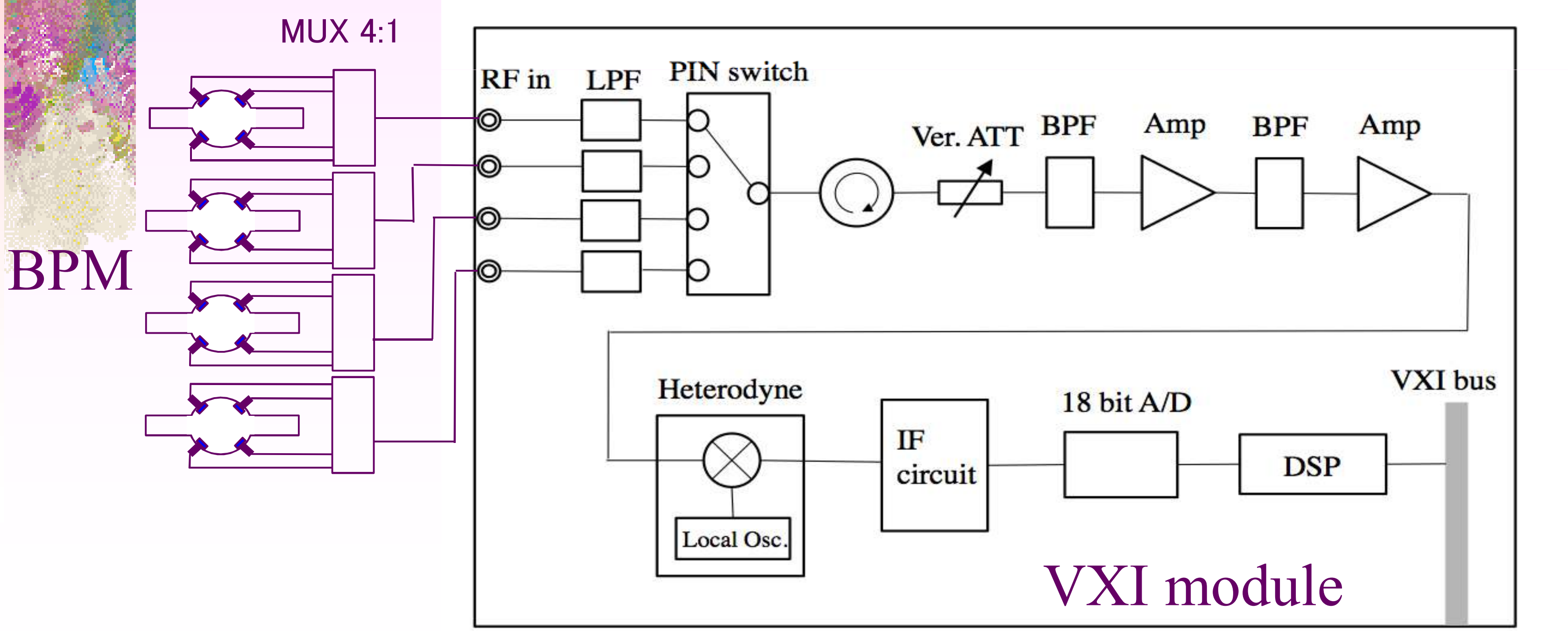
BPM block at wiggler sections

BPM block in arc sections

509 MHz Narrowband Detector

- Twenty 509 MHz narrowband detectors have been ordered in this FY.
- Mass production of 120 units is scheduled in next FY.

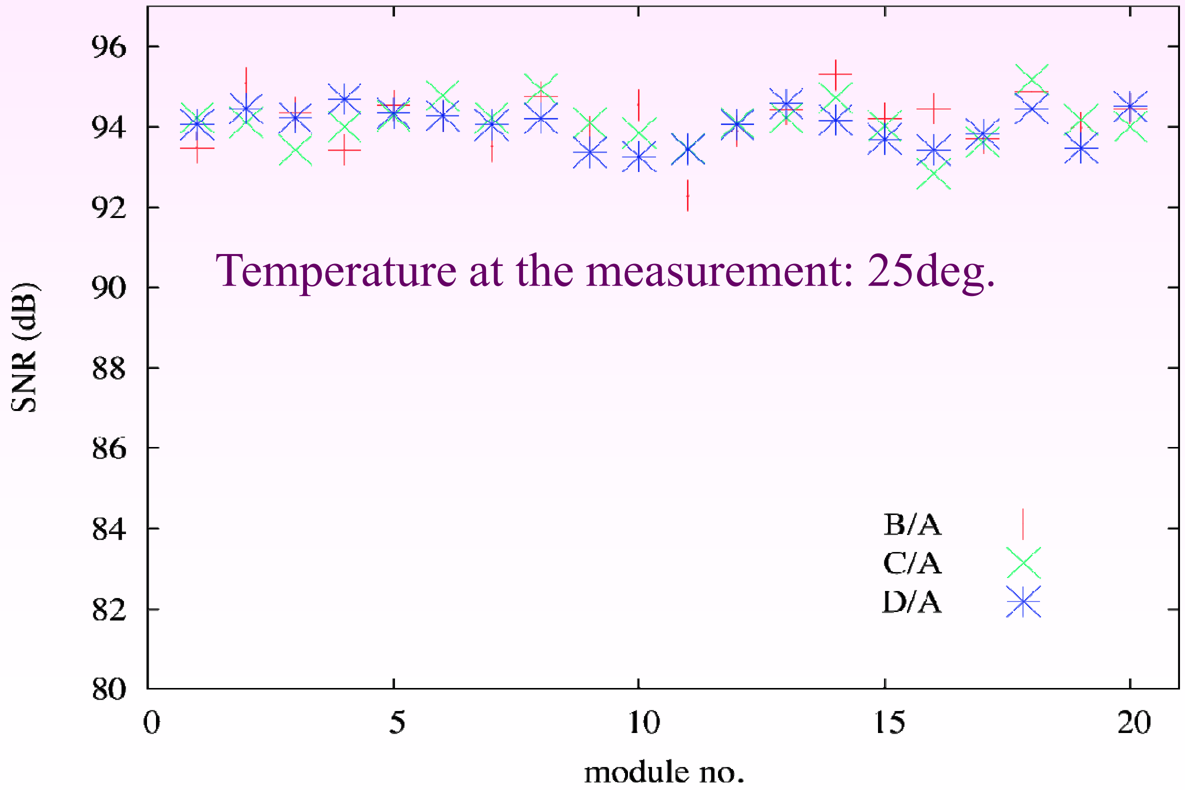
Super heterodyne detector with 509MHz detection



509 MHz Narrowband Detector : Performance (tentative)

•Performance of the detectors is being measured at the company as part of the production.

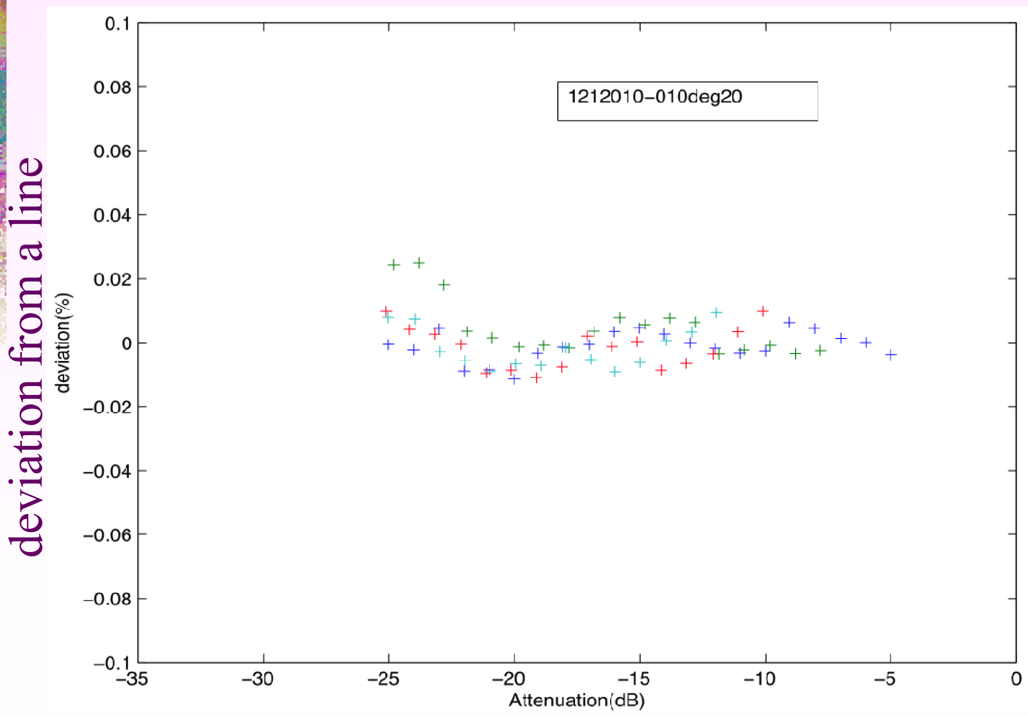
1) Ratio SNRs (B/A, C/A, D/A) are larger than 90 dB.
   (A, B, C, D : voltages of four electrodes)



2) Apparent position shift by changing attenuation of the variable attenuator from 0 to 55dB is about 3 μm p-p.

3) Linearity is better than 0.05% in the voltage range of 1/4 full scale to full scale.

Channel A

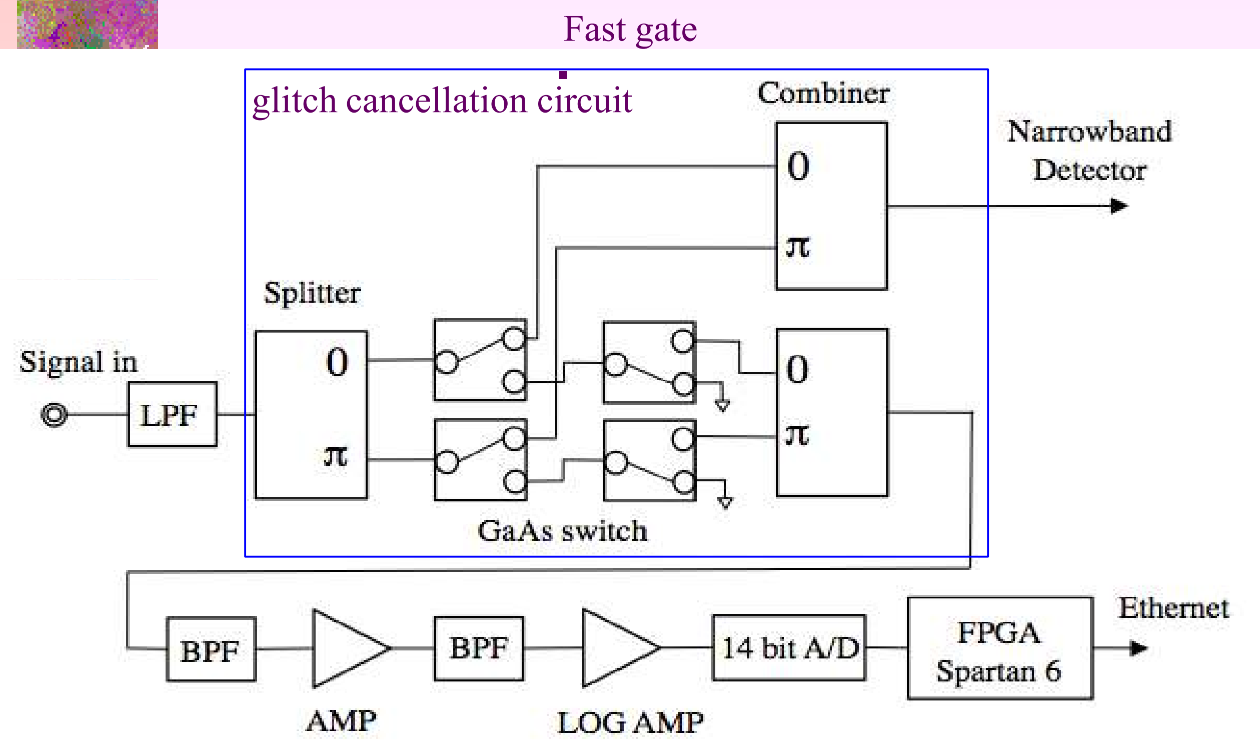


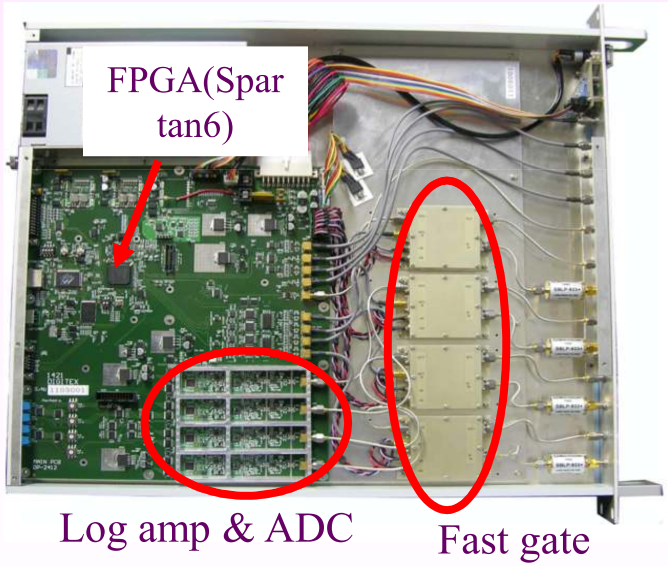
Example of linearity analysis

- Linearity was measured by changing input power level with variable and fixed attenuators.
- Attenuation at each setting of the attenuators was calibrated by the fit to data.

Gated turn-by-turn detector

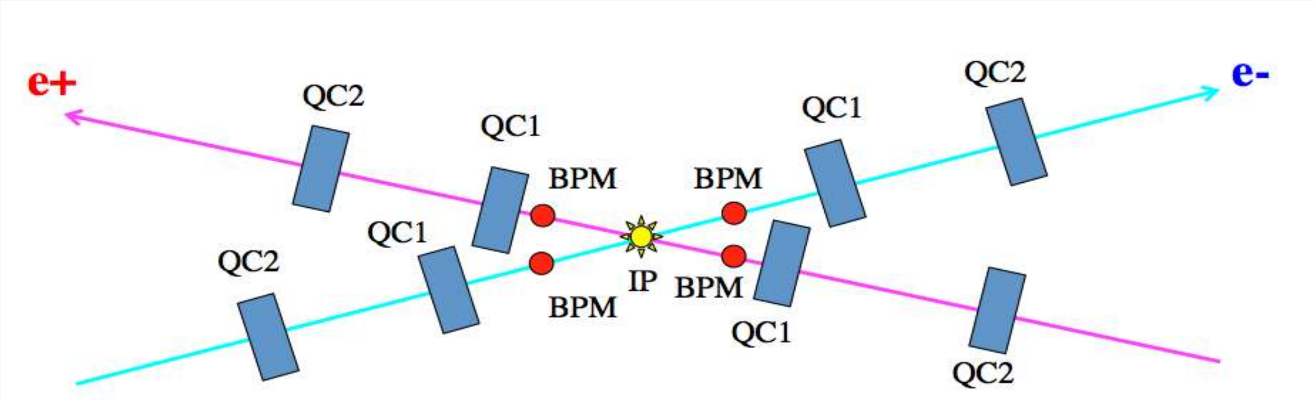
- Twelve turn-by-turn detectors have been ordered in this FY.
- 60 turn-by-turn detectors will be ordered in next FY for Phase 1.





Switch : Hittite GaAs MESFET, DC – 12GHz
Log amp : ADL5513 (AD)
ADC : ADS850 (TI)

IP Feedback Detector

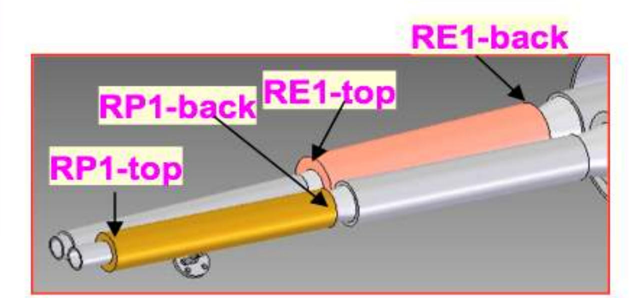


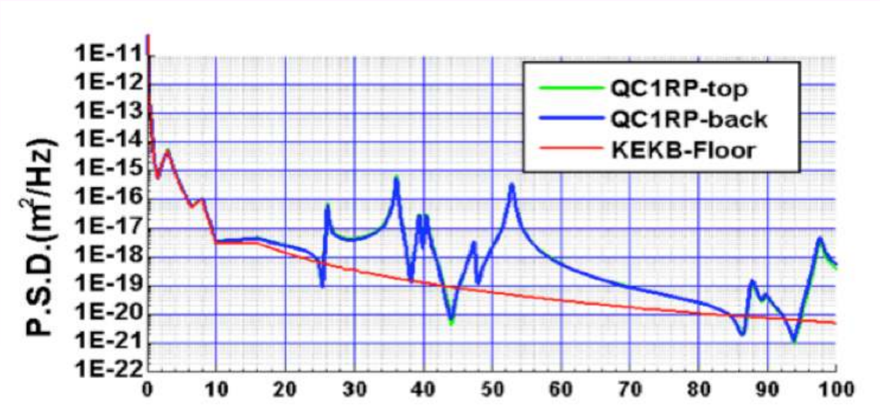
Main sources of orbit movement: vibration of quadrupoles closest to IP

Main frequency components: 3, 36, 53Hz (simulation)

Tentative specification for the detector

- Resolution < 1 μm
- Repetition 5kHz
- Bandwidth 1kHz





Movement of QC1RP by a simulation (H. Yamaoka)

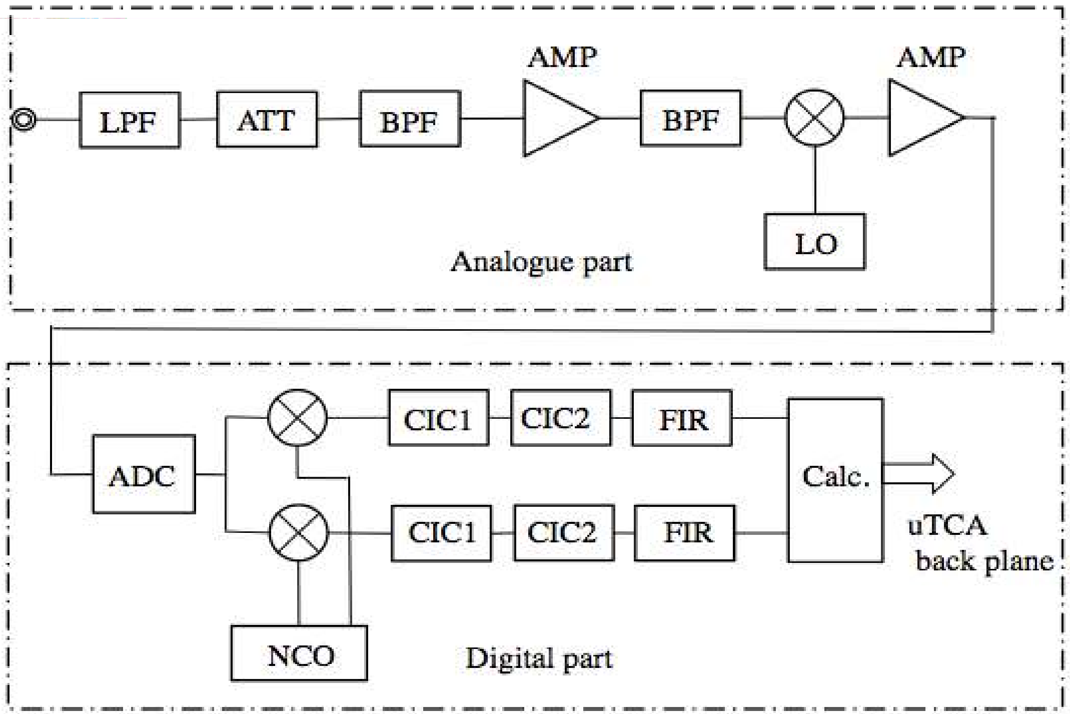
IP Feedback Detector : Detector

•Down-convert 508.8MHz component to intermediate frequency (IF) of 16.9 MHz with an analog mixer to reduce the degradation of the SNR by the clock jitter of ADC.

} Analog part

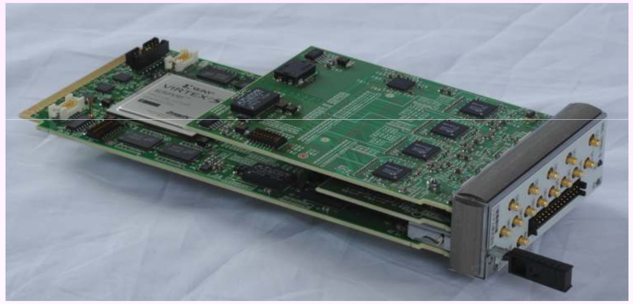
•AD conversion
•Digital filters (2 CICs, 1 FIR)
• Position calculation

} Digital part



Prototype

μTCA



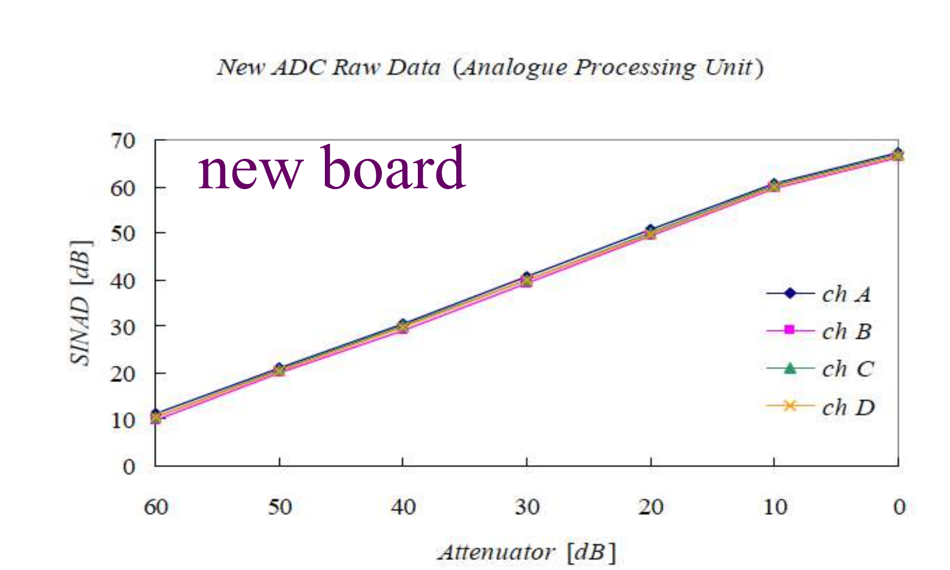
Digital processor board

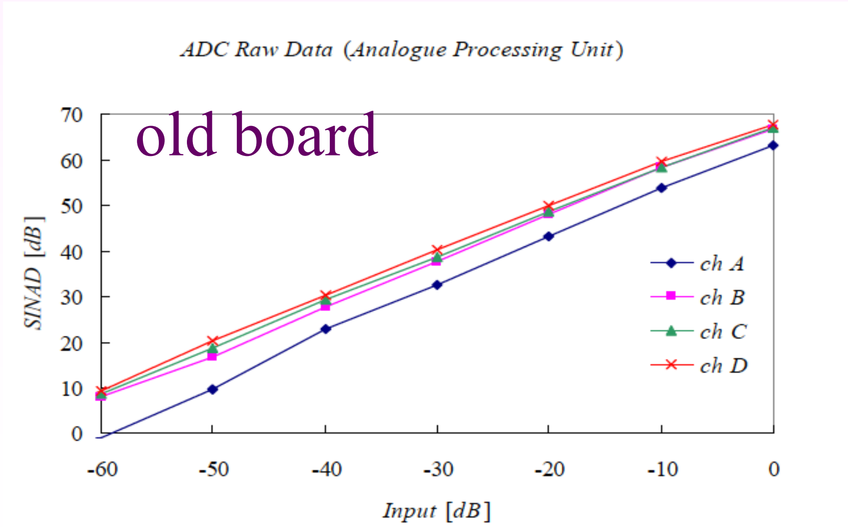
•The digital part is implemented in a μTCA board developed for SuperKEKB LLRF system.
•EPICS is embedded in the board.

IP Feedback Detector : Activity in this FY

1) New digital processor board
   - A new digital processor board developed for LLRF was tested.
   - Difference of SINAD among four channels is improved comparing with the old module.
   - 73-taps FIR was implemented to reduce the group delay to 1ms.

A measurement showed that resolution is about 0.1μm after the change of FIR.





Comparison of SINAD between old and new LLRF digital boards.

2) Improvement of analog part

a)Expansion of dynamic range of the down converter to remove saturation of SINAD.

Rearrangement of level distribution through circuit elements by removing LNA and using a high P1dB(30dBm) and high gain(36) IF amp.

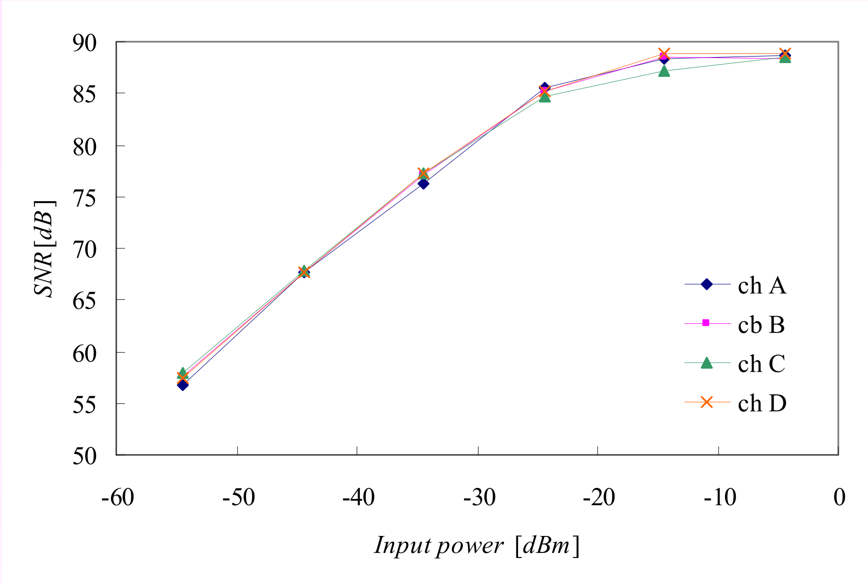
b)Phase noise improvement

- Replacement of the switching power unit with a series dropper regulator.
- A new oscillator board for sampling clocks and local signals

Separation of power lines between analogue and digital parts

Hoping for clock jitter reduction from 1.66 ps to 1ps.

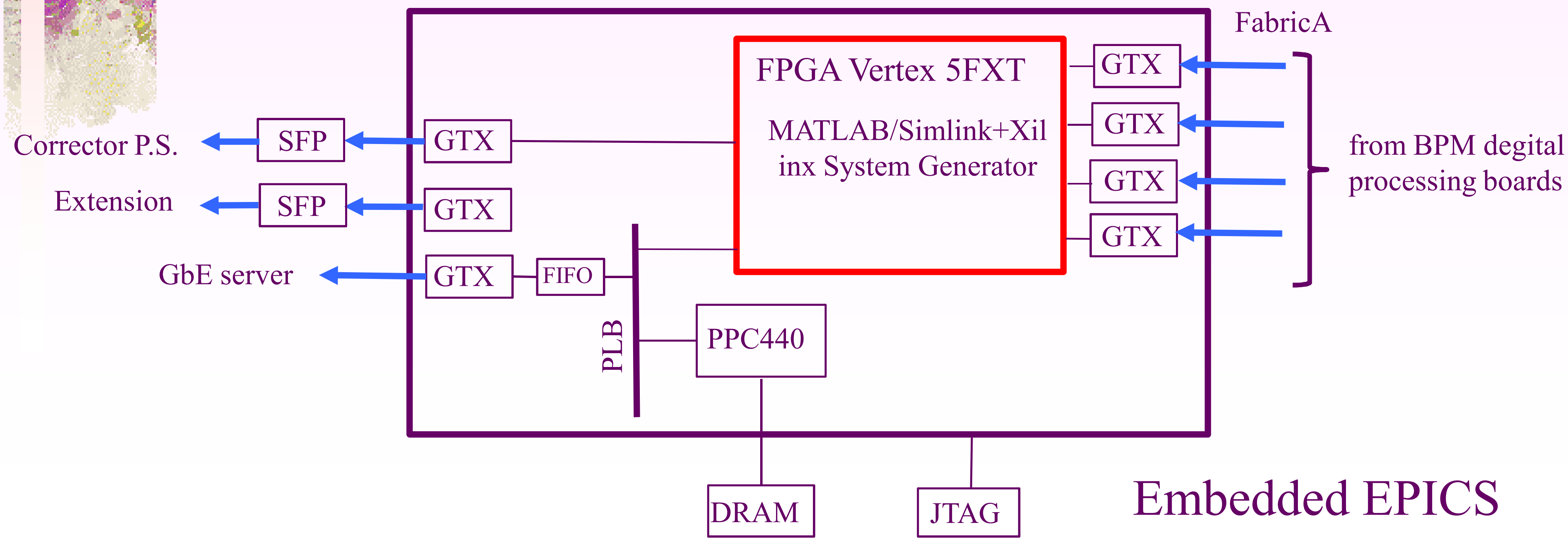
The modified circuit will be tested this spring.



Saturation of SNR

IP Feedback processor unit (μTCA)

- Prototype of a feedback processor module has been made.
- Implemented with Matlab/Simulink with system generator (HDL coder) for easy coding.
- Simple PID algorithm is implemented now.
- We are planning a feedback simulation using Co-simulation with Simulink and the ML507 evaluation kit.
- A receiver and a power supply interface will be developed in next FY.



Embedded EPICS

Libera brilliance+ (by Instrumentation Technologies)

- We are considering the use of commercial Libera based detectors for medium band detectors, orbit interlock modules and longitudinal phase monitors.

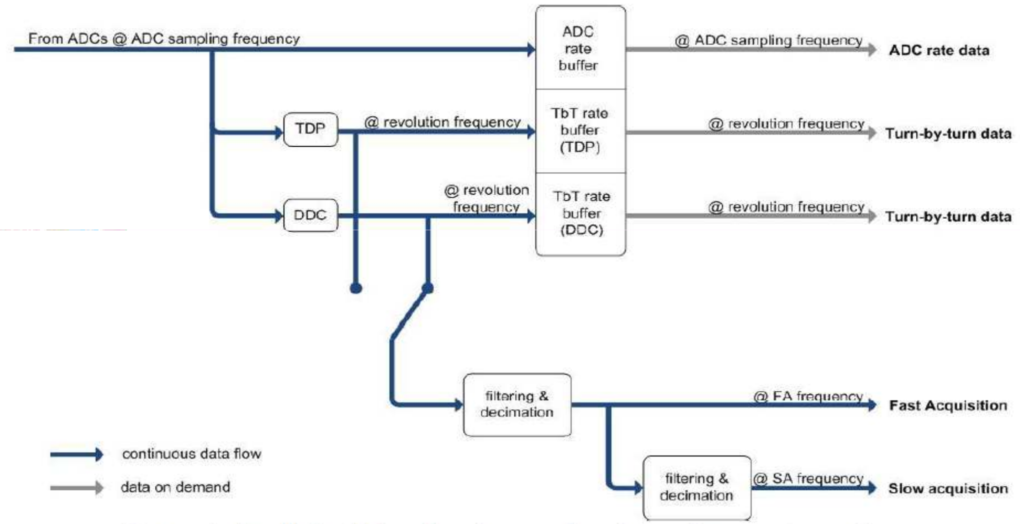


Figure 4: Parallel wideband and narrowband signal processing paths

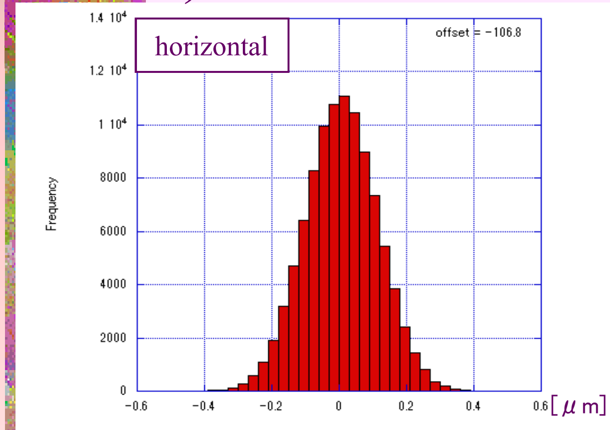
Parameter	Range	Guaranteed performance, k=10mm			
		Libera Brilliance+ (TBT=131kHz)		Libera Brilliance+ (TBT=1.15MHz)	
		non switched	switched	non switched	switched
Resolution (turn-by-turn)	→-28 dBm	1 µm	1 µm	3 µm	3 µm
	→-44 dBm	5 µm	5 µm	15 µm	15 µm
Beam Current Dependence	0→-24 dBm	1 µm		1 µm	
	0→-32 dBm	1,5 µm		1,5 µm	
	0→-50 dBm	2 µm		2 µm	
Fill Pattern Dependence	100%-20% duty cycle	1 µm		1 µm	
FA Resolution	0→-20 dBm	0,25 µm		0,25 µm	
Crosstalk		-50 dB			

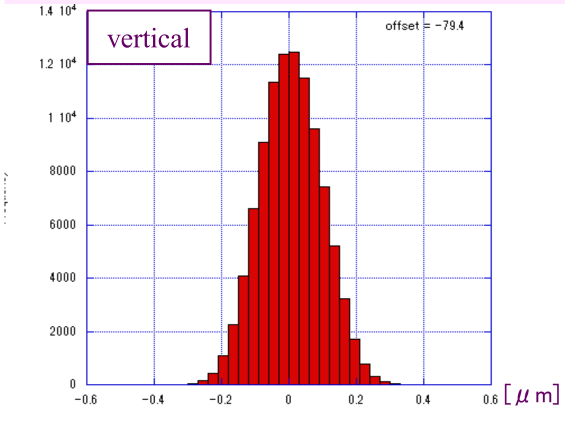
Table 6: Libera Brilliance+ performance

- Three acquisition modes : Turn-by-turn, FA (repetition 10kHz), SA (repetition 10 Hz)
- One Libera brilliance+ was purchased and is being tested at laboratory.

Bench test of Libera brilliance+

1) Resolution

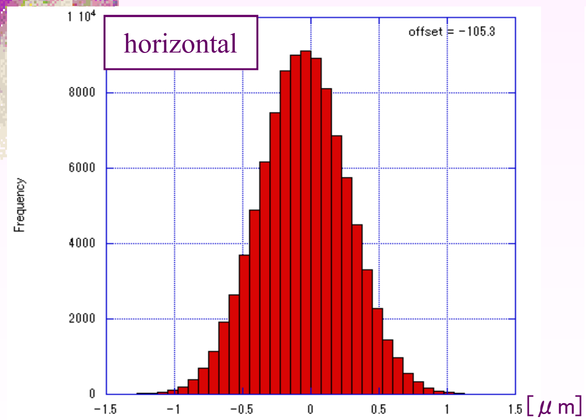


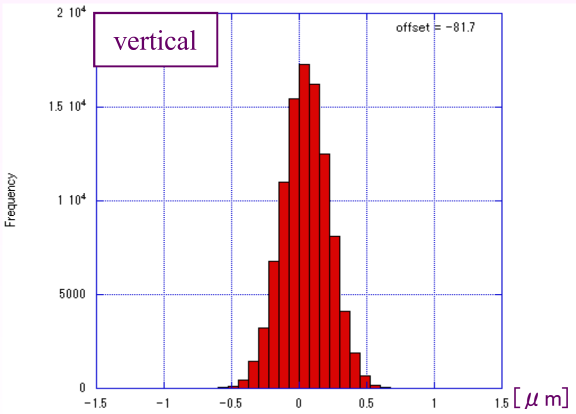


Measurement of resolution of FA data

horizontal	vertical
0.105 [μm]	0.075 [μm]

(r.m.s.)





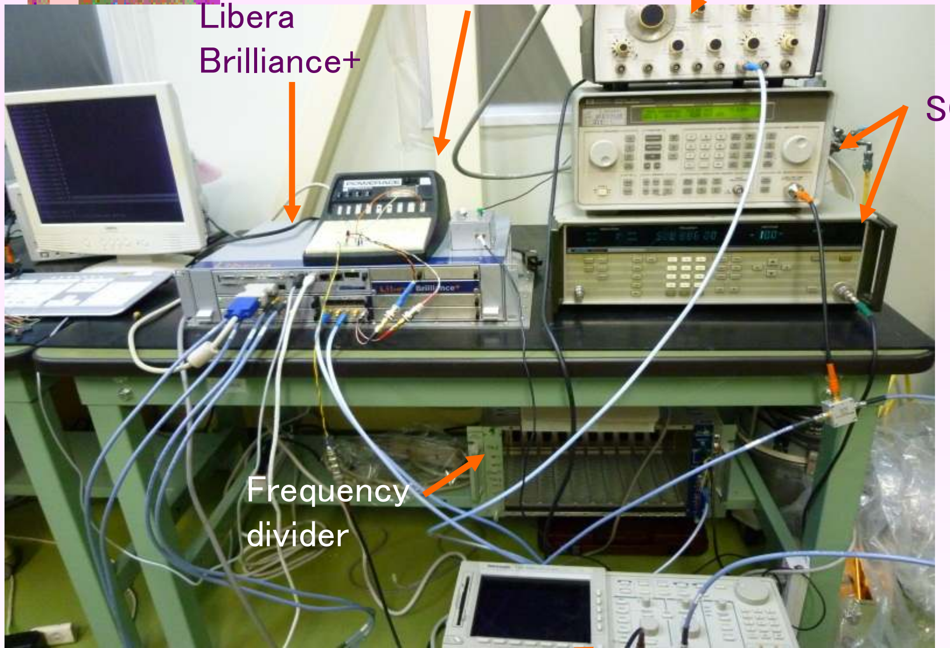
Measurement of resolution of Turn by Turn data

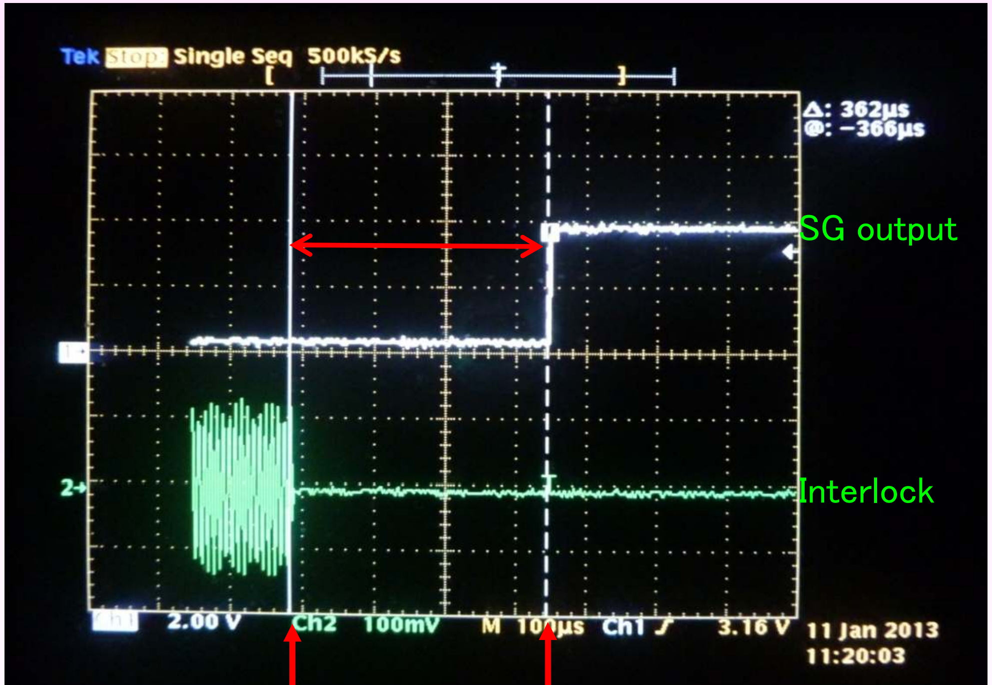
horizontal	vertical
0.310 [μm]	0.160 [μm]

(r.m.s.)

The resolution is good enough for the medium-band detector.

2) Interlock latency





Latency

400±50µs (40 turns ≈ a synchrotron period)

Probably, the latency is not short enough for our purpose .

The assessment by the company shows interlock latency will be reduced to a few turns by using Turn-by-Turn data if software is modified.

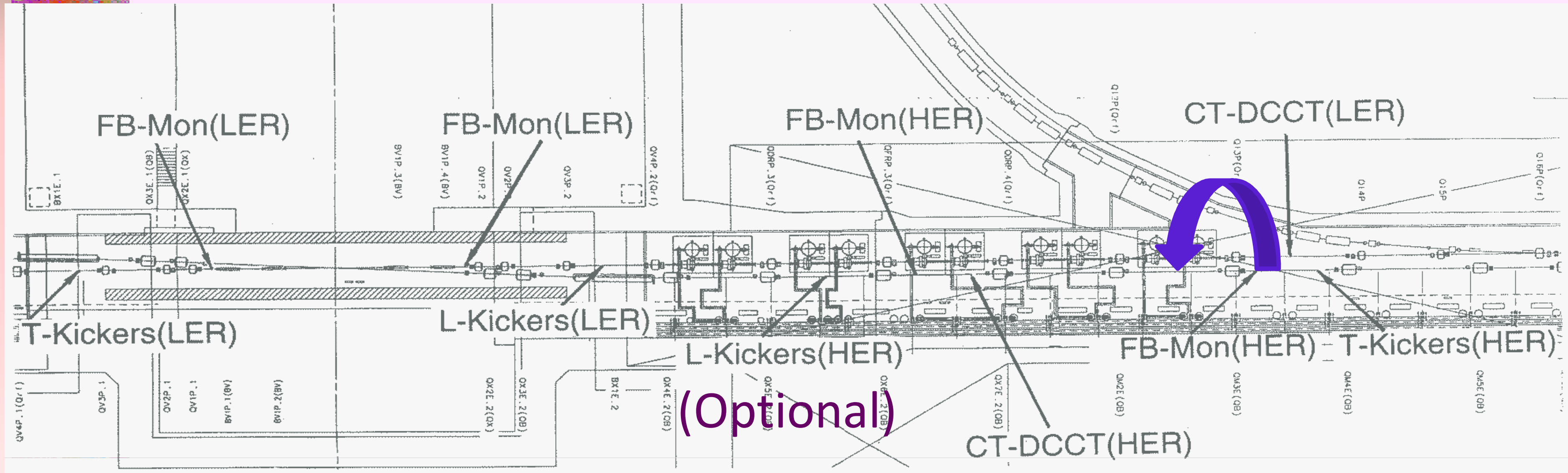
Main work in next FY

- Production of 120 509MHz detectors
- Production of 60 gated turn by turn detectors
- Development of a receiver and power supply interface for IP orbit feedback.
- Development of a feedback algorism in the IP Feedback processor unit.
- Order/fabrication of the medium-band detectors, the orbit interlock modules and the longitudinal phase monitors.
- Design and fabrication of displacement sensors at rotatable sextupoles.
- Purchase of signal cables and so on.
- Schedule of cable connection of BPMs is not decided yet because it strongly depends on vacuum, magnet and facilities work in the tunnel.

Bunch Feedback Systems

Preparation status

- Most of the hardware needed for the SuperKEKB rings (HER, LER, DR) will be ready by the end of this FY.
  - Bunch detection circuits
  - iGp12 digital filters
  - Digital QPSK back-end
  - Temperature monitor systems
  - Position monitor chambers
  - Transverse kickers
    - Longitudinal kickers : still in design stage
  - High power final amplifiers (Transverse, Longitudinal)
  - 1.5kW high power attenuators
  - Circulators, low-pass filters for Longitudinal Kickers
  - High power cables, bpm cables



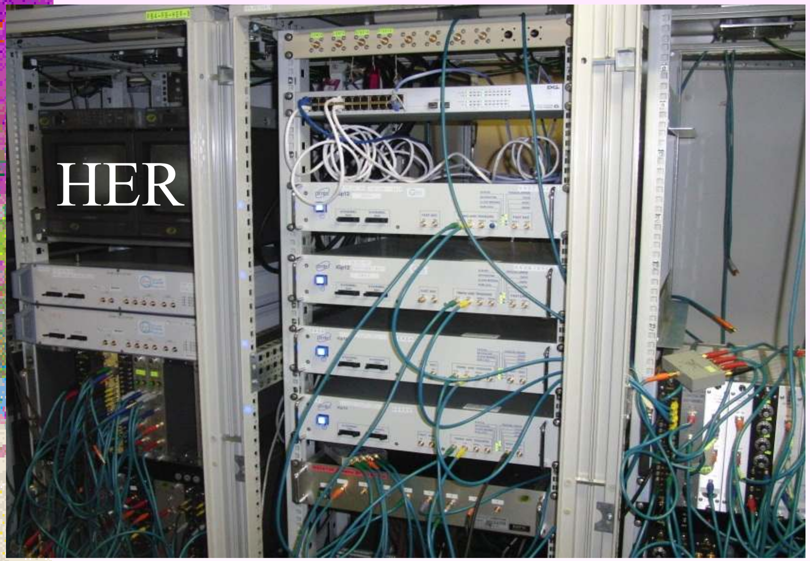
New FB monitor using glass-type sealing feedthroughs (all)

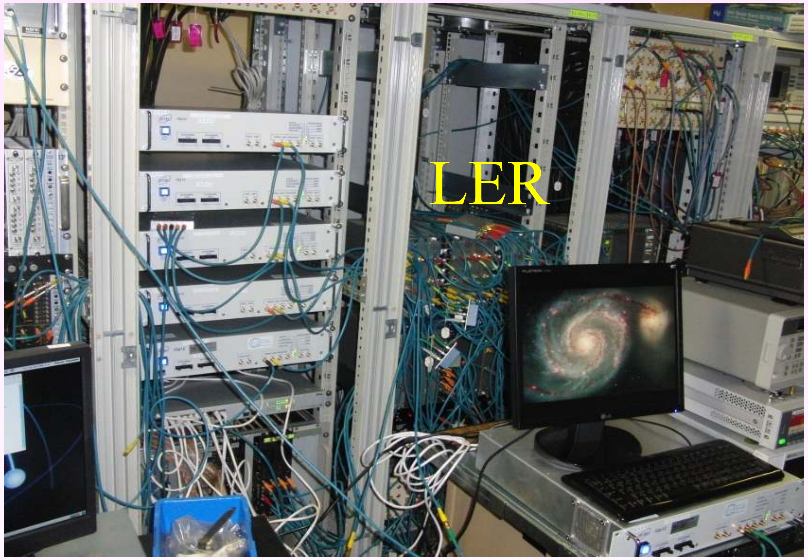
Move HER Upstream monitor one section downstream to adjust phase advance

Add another transverse stripline kicker next to the original one

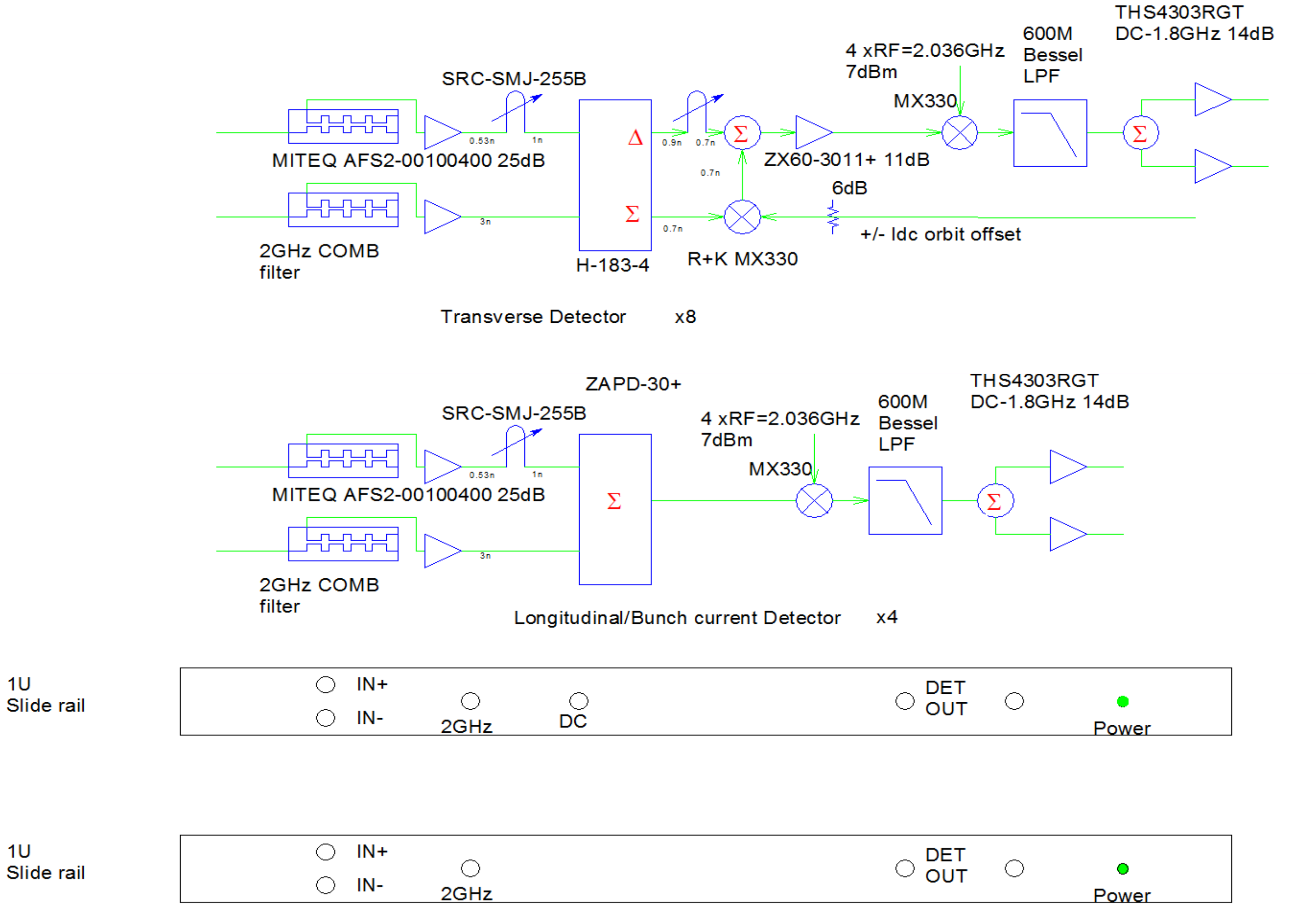
Prepare better longitudinal kickers for LER. HER is optional.

iGp12s





Bunch detection electronics



Power amplifiers

- Transverse power amplifiers
  - 10k-255MHz Pmax=500W amplifiers

    R+K : 10 units ready (2 for spares)
  - 10k-255MHz Pmax=250W amplifiers

    (AR250A250, used for KEKB) : 11 units ready
    - 8 for SuperKEKB MR, 3 for Damping Ring
- Longitudinal power amplifiers
  - 900MHz-1.8GHz Pmax=500W amplifiers

    R+K : 8 units ready

    Milmega : 2units ready (for spares)

High power amplifiers

Next FY

- Fabricate longitudinal kickers for LER
- Re-arrange the local control room (FB4) to install new detection circuits
- Cabling work (High power, bpm, temperature monitor)
  - Installation of vacuum components? (Depends on vacuum schedule.)
- Tuning of the digital circuits (iGp12, iGp8, bunch current monitors, etc)
  - Mainly FPGA firmware
- Special monitors related to bunch feedback systems
  - Pilot bunch excitation using PLL tech. (by iGp12?)
  - Gated measurement systems (tune, beam-beam kick) using old BOD?

Photon Monitor System

Photon Monitors

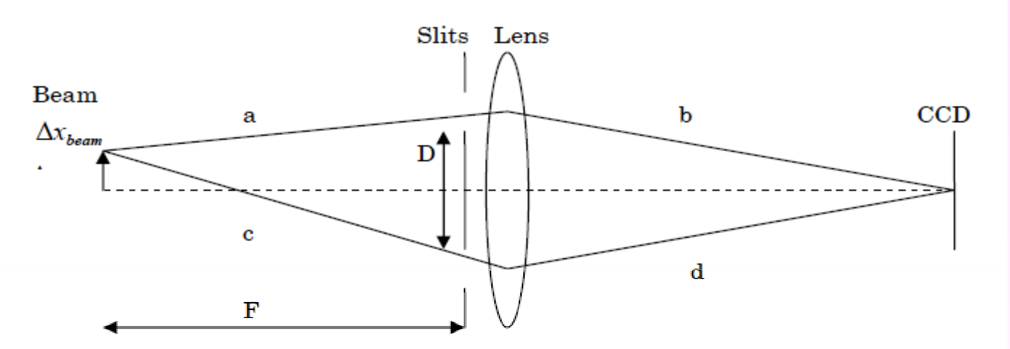
- SRM: Synchrotron Radiation Monitor
  - Visible light monitor, Interferometer, streak, etc.
  - σ_z, σ_x (σ_y)
- XRM: X-ray Monitor
  - Pinhole, URA mask, etc.
  - σ_y (σ_x)
- LABM: Large Angle Beamstrahlung Monitor
  - SR-like radiation from interaction point (~300-600 nm)
  - Can measure relative offsets and size ratios at collision point.

- CSM: Compton-scattering based beam energy monitor
  - Brand new subject, collaboration with SLAC under US-Japan program, and possibly BINP.
  - Not much to say about this yet!

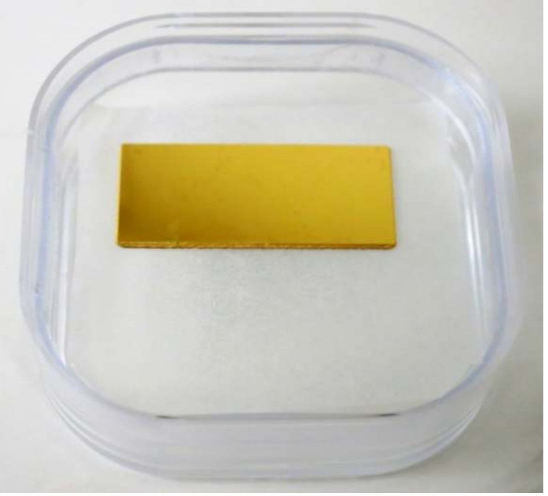
SRM: Interferometers

SR Source Bend Parameter	S-LER1 (BSWFRP)	S-HER (BSWOLE)	Units
ε_x	3.20E-09	4.60E-09	m
κ	0.27%	0.24%	
ε_y	8.64E-12	1.10E-11	m
β_y	29.98	32.49	m
σ_y	16.1	18.9	μm
Beam Energy	4	7	GeV
Bend effective length	0.89	2.90	m
Bend angle	5.04	5.00	mrad
Bend radius ρ	179.0	580.0	m
Observation wavelength λ	4.00E-07	4.00E-07	m
SR Opening angle θ_c (λ)	1.0	0.7	mrad
Slits opening angle D/F	0.7	0.7	mrad
Max. Visibility (fringe depth) γ_{max}	99%	99%	
Min. measurable beam size $\sigma_{y\ min}$	12.8	13.5	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.



- Vertical beam size measurement is possible with interferometers, though is near the limit of the interferometer resolution, and single-shot measurement is not possible.
- To minimize deformation due to heat load, gold-coated diamond mirrors are under development.
  - 28 mm x 18 mm prototype in fabrication now.
- Cavities below optics hut floors in D4 and D8 klystron galleries have been filled to reduce the amount of floor vibration, which had been a problem during KEKB operation.
- D4 hut has been expanded to accommodate second optical table and x-ray monitor readout space.



Diamond mirror prototype

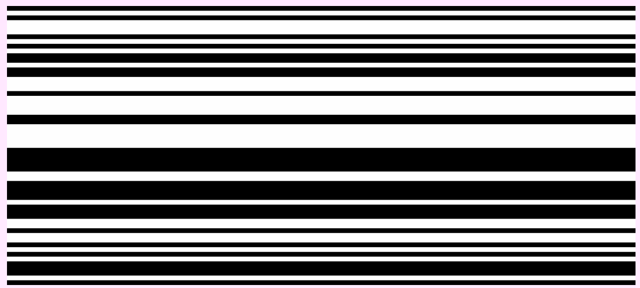
SRM: Summary

- Reuse present source bend locations
  - LER bend becomes longer, to reduce heat load
  - HER remains the same
- Move extraction chambers downstream ~few meters
  - Put mirror in antechamber for reduced impedance
- Floors under above-ground tunnel components have been reinforced to reduce vibrations
- Transfer lines will be rebuilt to be better sealed against air flow
- σ_z: Streak Camera→OK
- σ_x: Interferometer→OK (not single-shot, though)
- σ_y: Interferometer
  - Will be difficult to get required resolution
  - Not possible to get single-shot (single bunch, single turn) measurements, which will probably be needed for low-emittance tuning, based on experience at CesrTA.
  - However, should be useful for cross-checking with x-ray monitor at larger beam sizes.

XRM: 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 and flux-limiting monochromator not needed.

We need such a wide aperture, wide spectrum technique for shot-by-shot (single bunch, single turn) measurements.



Uniformly Redundant Array (URA) for x-ray imaging to be used at SuperKEKB

Source distribution:

$$\begin{bmatrix} A_\sigma \\ A_\pi \end{bmatrix} = \frac{\sqrt{3}}{2\pi}\gamma\frac{\omega}{\omega_c}\left(1+X^2\right)(-i)\begin{bmatrix} K_{2/3}(\eta) \\ \frac{iX}{\sqrt{1+X^2}}K_{1/3}(\eta) \end{bmatrix},$$

where

$$X = \gamma\psi,$$

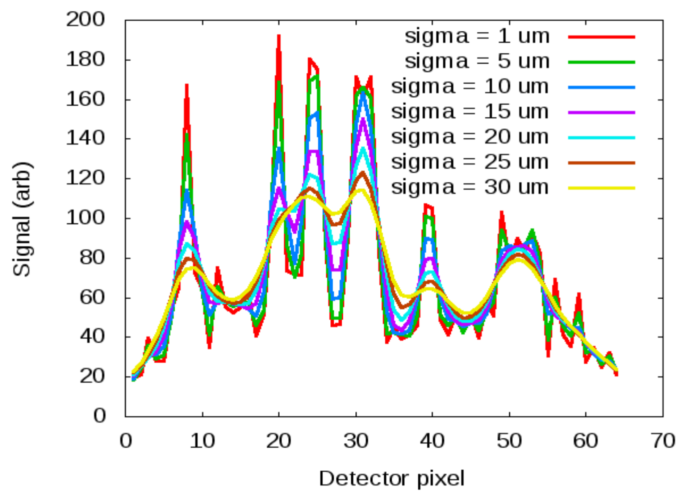
$$\eta = \frac{1}{2}\frac{\omega}{\omega_c}\left(1+X^2\right)^{3/2},$$

+

Kirchhoff integral over mask (+ detector response)

→ Detected pattern:

$$A_{\sigma,\pi}(y_d) = \frac{iA_{\sigma,\pi}(\text{source})}{\lambda}\int_{\text{mask}}\frac{t(y_m)}{r_1 r_2}e^{i\frac{2\pi}{\lambda}(r_1+r_2)} \times\left(\frac{\cos\theta_1+\cos\theta_2}{2}\right)\mathrm{d}y_m,$$

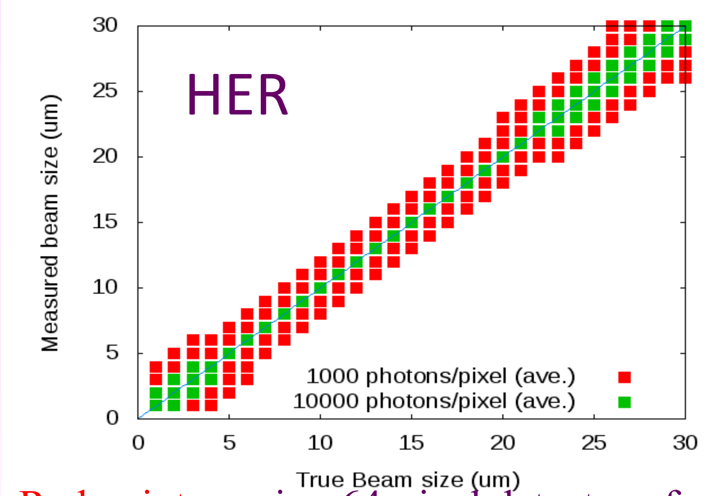


Simulated detector response for various beam sizes at SuperKEKB LER

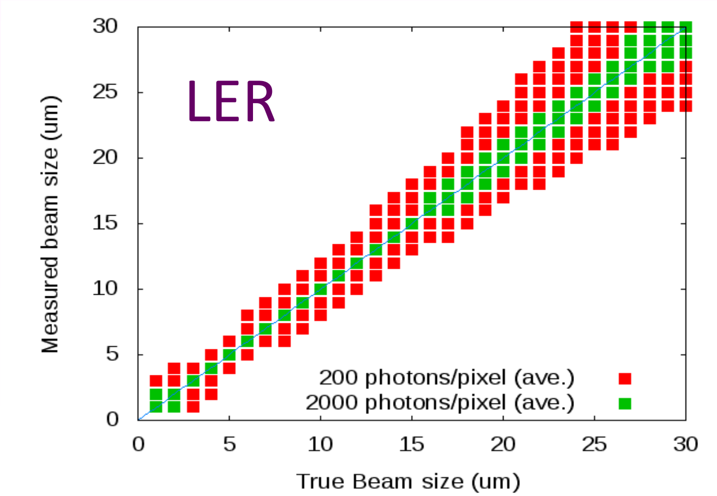
XRM: SuperKEKB x-ray monitor

Xray Source Bend Par.	S-LER (BS2FRP.1)	S-HER (BS2E.82)	Units
ε_x	3.20E-09	4.60E-09	m
κ	0.27%	0.24%	
ε_y	8.64E-12	1.10E-11	m
β_y	50.0	11.5	m
σ_y	20.8	11.3	µm
Beam Energy	4	7	GeV
Effective length	0.89	5.9	m
Bend angle	28.0	55.7	mrad
ρ	31.7	105.9	m
Critical Energy	4.4	7.1	keV

- Mask:
  - 59-element, 10 µm/element URA
  - High-power design
    - 10 µm Au mask
    - 625 µm Si or CVD diamond substrate
    - Test at CesrTA
  - Other patterns, materials under study
- Detector:
  - 64-channel, 50 µm InGaAs detector (same as at CesrTA) can be used at first.
  - For better detection efficiency at 10-20 keV (SuperKEKB), deep-pixel design being developed at SLAC under the US-Japan program.

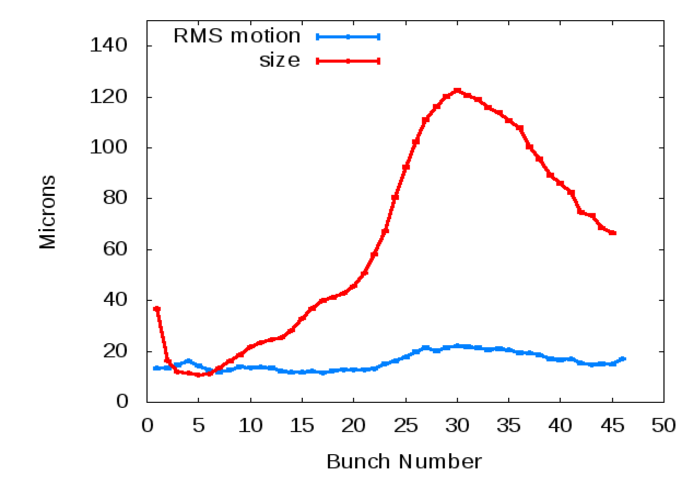


- Red points: using 64-pixel detector of same type as at CesrTA (Fermionics)
- Green points: using detector with improved photon detection efficiency at higher x-ray energies (to be developed)



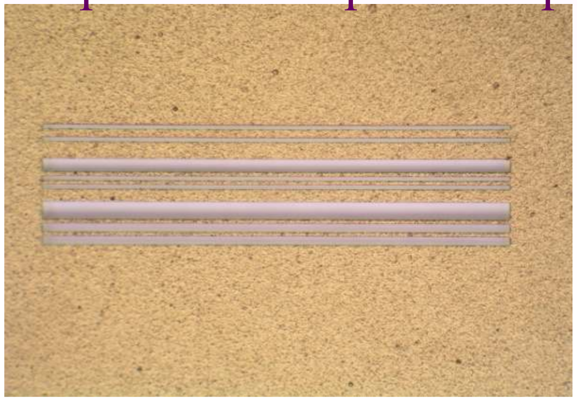
XRM: Coded Aperture tests at CesrTA

- Low-energy masks:
  - Continued study of systematics in analysis of coded aperture data.
  - Coded aperture regularly used for electron-cloud and Intra-Beam Scattering (IBS) studies.
  - Evaluated new designs for low-energy mask, selected one design (Cornell design) for testing at CesrTA in 2013.
- High-energy mask high-power tests:
  - Au+Si mask tested at 120% of SuperKEKB SR power load
    - Melted!
  - Au+Si mask survived at 100% previously.
  - Flaw in heat sink design possible -- will change design for SuperKEKB.
  - Au+CVD (diamond) mask installed for testing in April 2013
    - Will use factory-damaged mask for burn test at D Line.
    - Will use good mask for imaging test at C Line.

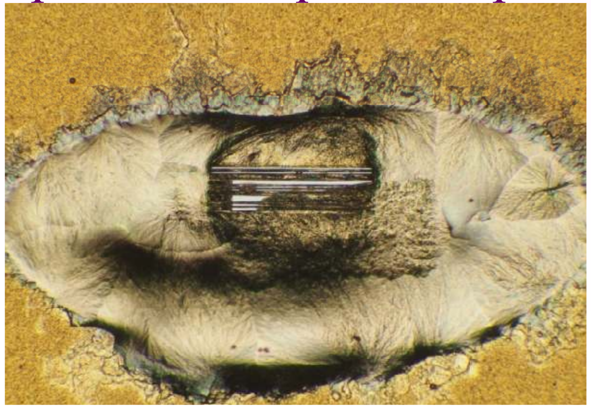


Examples of bunch-by-bunch data (electron-cloud blow-up study data)
Single-shot data average for each bunch

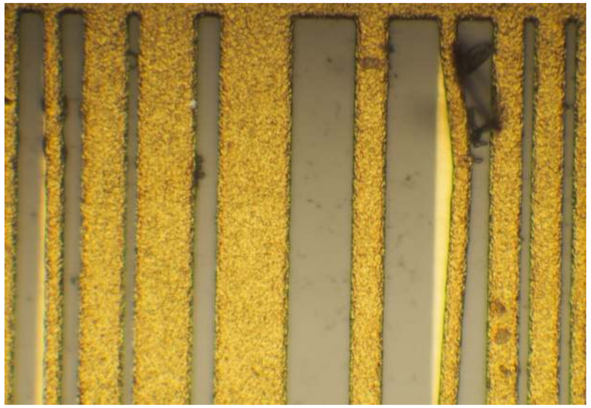
Au+Si mask after 100% SuperKEKB equivalent power:



Au+Si mask after 120% SuperKEKB equivalent power:

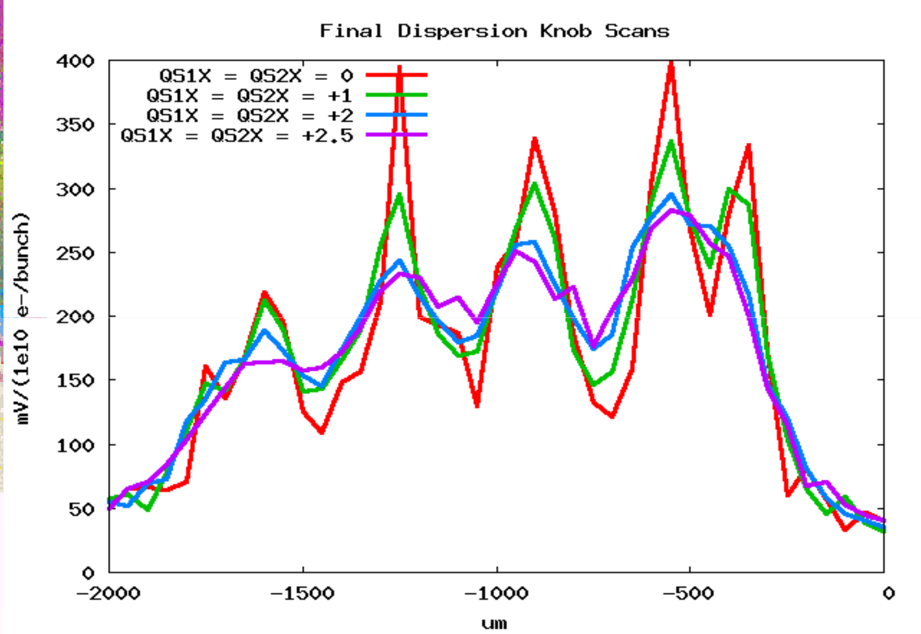


Factory-damaged Au+CVD mask for burn test:

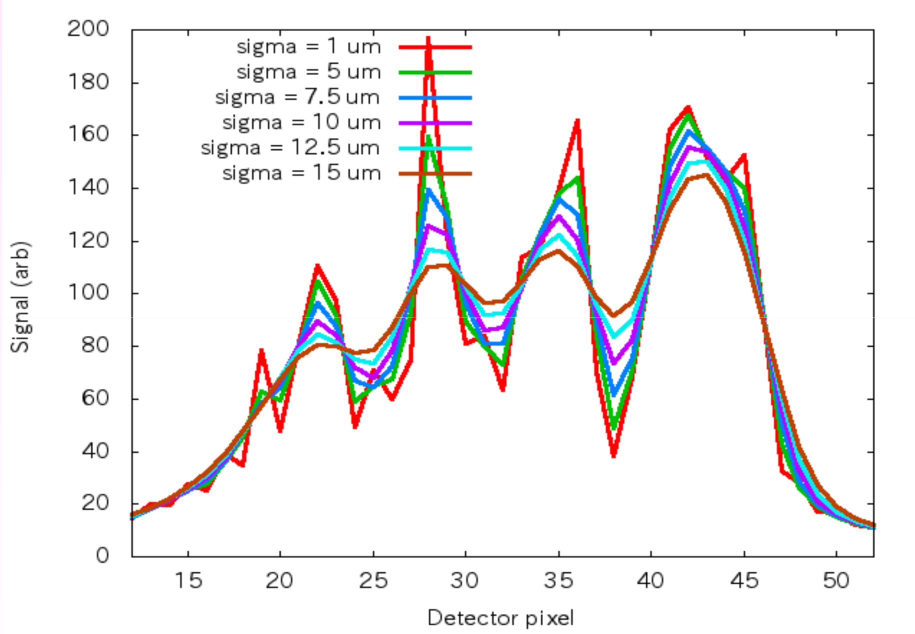


XRM: Coded Aperture tests at ATF2

Data: Dispersion Knob Scans



Simulations

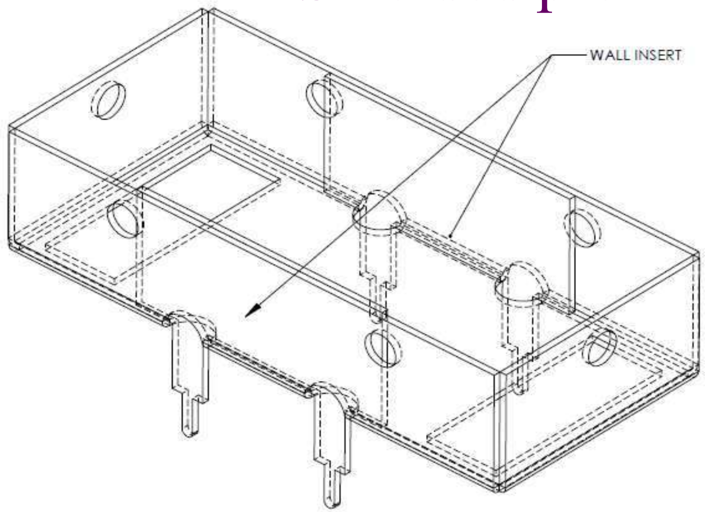


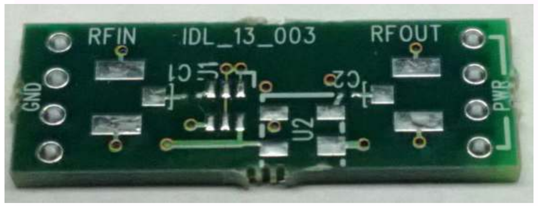
Measured beams of 7.5 µm or less with scanned-pixel measurements
→New world record for coded aperture measurements

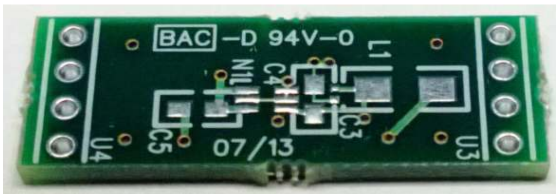
XRM: Readout development

- High-speed readout for SuperKEKB (U. Hawaii)
  - Evaluated STURM2 motherboard design in lab and at U. Hawaii XFEL.
  - Based on results, have redesigned motherboard layout, especially:
    - Improved shielding for pre-amp daughter cards
    - Re-designed detector daughter card for improved signal impedance.
  - New boards designed and laid out, and fabrication started.
    - Plan to test at UH XFEL, and ATF2.

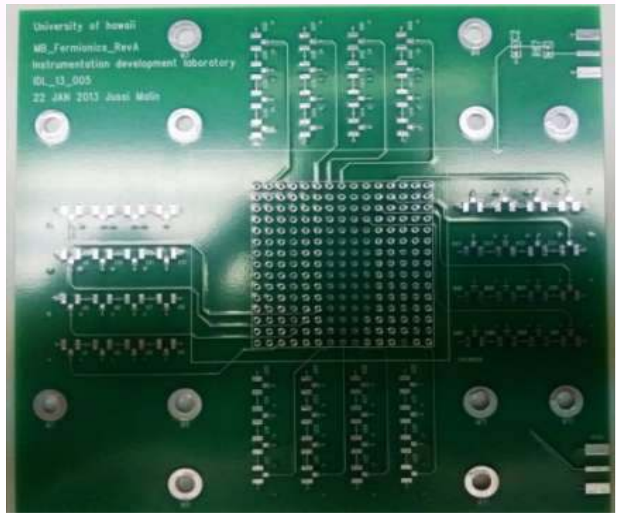
Shielded pre-amp daughter card:







New detector daughter card:

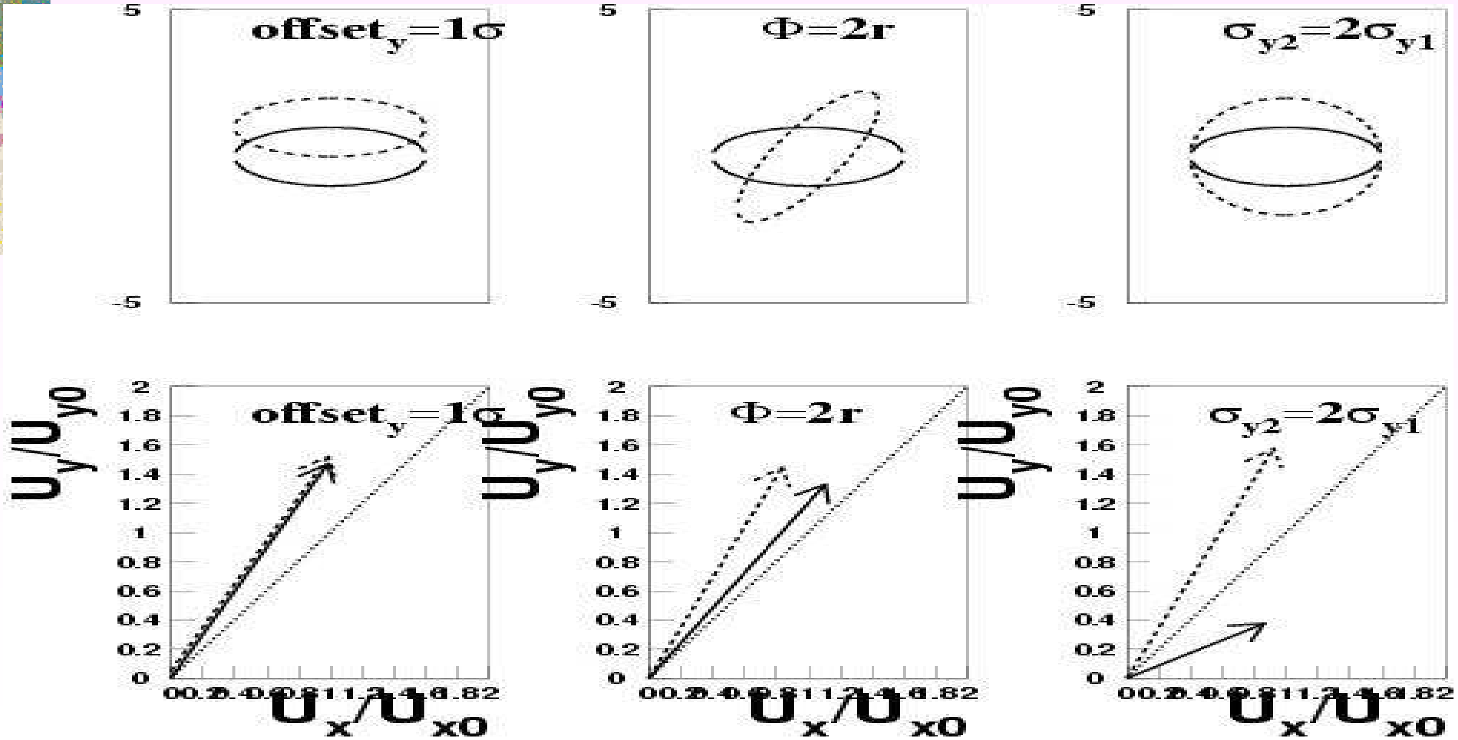


XRM: Summary

- Source bends upstream of SRM source bends
  - LER bend is reused KEKB LER bend magnet (at half strength)
  - HER uses same current arc bend magnet
  - Some modifications to magnets downstream of source point have been requested of magnet group, to accommodate x-ray extraction line.
- σ_y: Coded Aperture Mask
  - Single-shot (single-bunch, single turn) resolution expected to be sufficient.
  - Single-shot mode probably be needed for low-emittance tuning, based on experience at CesrTA.
- σ_x: Possible, if single-shot measurements are needed
  - SRM should work for this in slow integration mode
- Being developed in collaboration with Cornell U., U. Hawaii and SLAC
  - Testing different components at CesrTA and ATF2
- Development work continuing on detector and readout

LABM: Large Angle Beamstrahlung Monitor

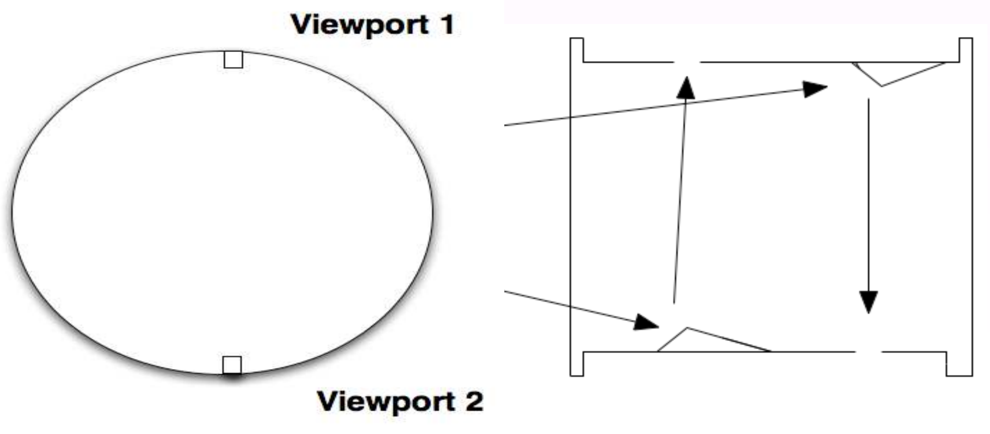
- The radiation of the particles of one beam due to the bending force of the EM field of the other beam
- Beamstrahlung POLARIZATION at specific azimuthal points provides information about the beam-beam geometry.

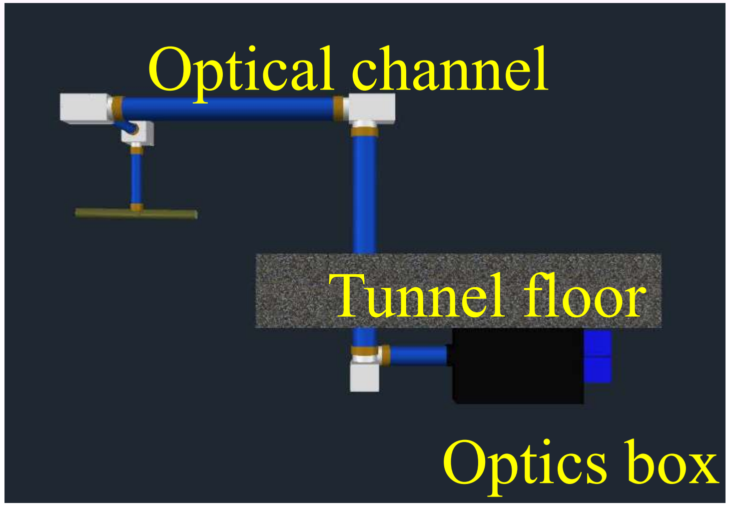


G. Bonvicini

LABM: Layout

- 4 viewports and associated 5.6 mm^2 mirrors on Beam Pipe (KEK), at 7-8 mrad w.r.t beam axis
- 4 narrow acceptance telescopes, which count photons in two polarizations and 4 bands (32 channels total, WSU)
- Build flexible electronics for a variety of beam measurements (Tabruk U. (Saudi Arabia), WSU)
- Be extraction mirror prototype (2 mm x 2.8 mm) and extraction windows fabricated. (KEK)





Beamstrahlung Monitor

2012 results (Wayne State U.):

- First (of two) optics box built and tested.
- Second optics box started.
- Remote-controlled primary mirror for optical transfer line built and tested.
- 24 elbows for optical transfer lines built.
- Electronics for readout at SuperKEKB under development with Tabruk U. (outside of Nichibei).
- Calculations for beam test at Frascati carried out.

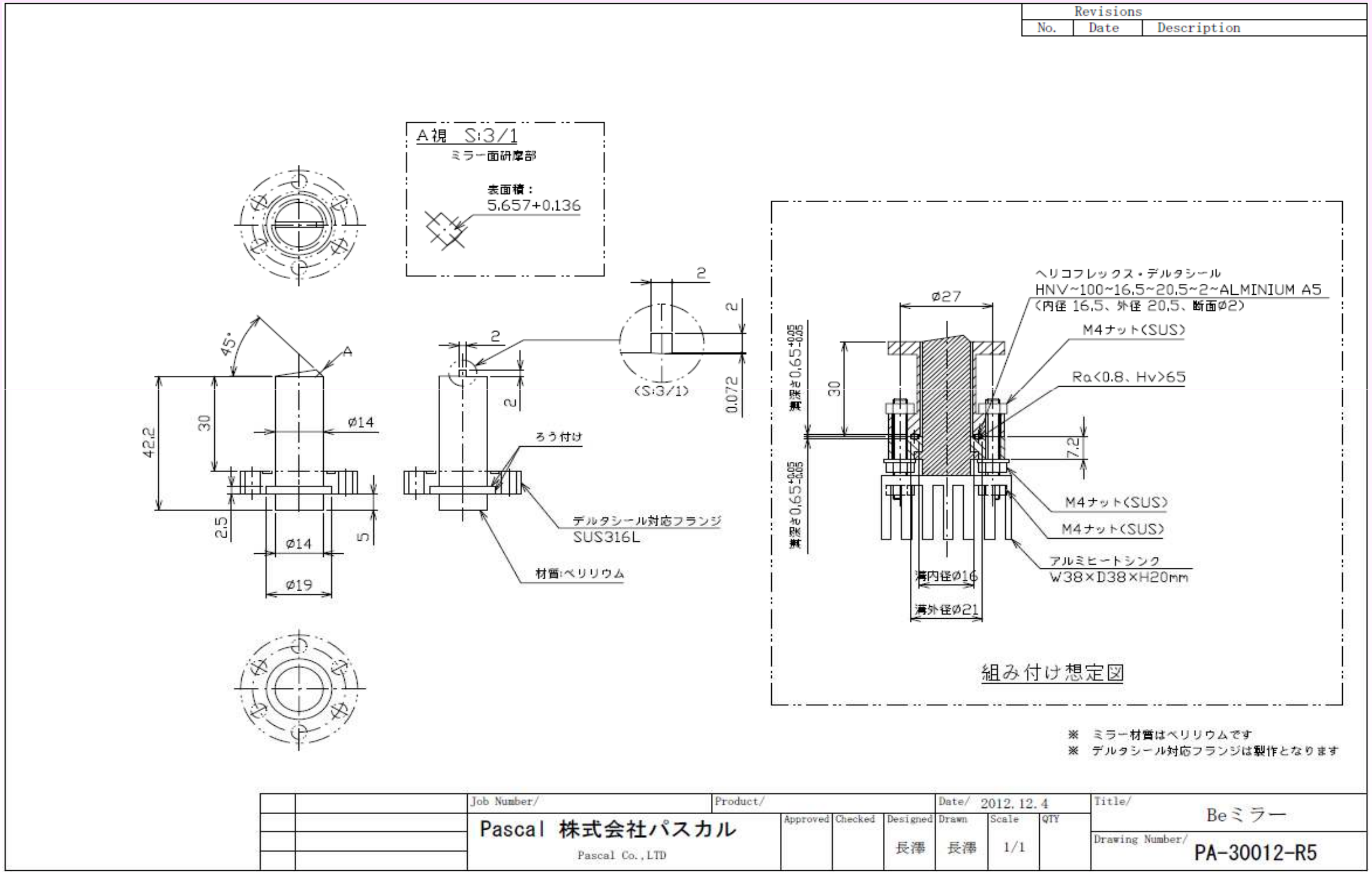
Prototype optics box

PMT mounts inside optics box

Final optics box

Movable mirror

LABM: Extraction mirror prototype (KEK)



Currently in fabrication

Beamstrahlung monitor

Plans for 2013

- At Wayne State:
  - Complete second optics box
  - Complete 3 more remotely controlled Primary Mirrors for optical transfer lines
  - Build relay line interfaces with accelerator extraction window flange
  - Precision bench test calibration of all viewports and PMTs of both optics boxes
  - Prepare for beam test at Frascati
    - Design and make optical transfer beam pipes and supports.
    - Beam test would start summer 2013, continue 10 months.
  - Finalize electronics (collaboration with Tabruk U.)
- At KEK:
  - Finalize design of extraction mirror, make production versions.
  - Extraction window flange hardware.

Photon Monitors Schedule

- 2013:
  - SRM
    - Final mirror prototyping and testing
    - Extraction chamber design
  - XRM
    - Continue heat and imaging tests with high-power optics at CesrTA
    - Continue Electronics and detector development
    - Construction of major components of extraction beamline.
  - LABM
    - Construction of second optics box and extraction mirrors.
    - Continue electronics readout development
    - Frascati beam test planned starting in summer, 2013.
  - CSM
    - Investigate design of system with SLAC and BINP.
- At SuperKEKB turn-on (non-collision):
  - SRM & XRM commissioning and emittance measurements
  - LABM commissioning and background studies
- Sometime soon after (real, non-bakeout) turn-on:
  - LABM comissioning and collision measurements
- Somewhat further ahead:
  - Compton-scattering-based beam energy monitor

Misc.

CT, DCCT

- Remodeling the original DCCT in progress
  - Exchange the old cables
  - New circuit to allow increase in maximum beam current from 3 A to 5 A
  - Tune the step response of DR DCCT if needed.

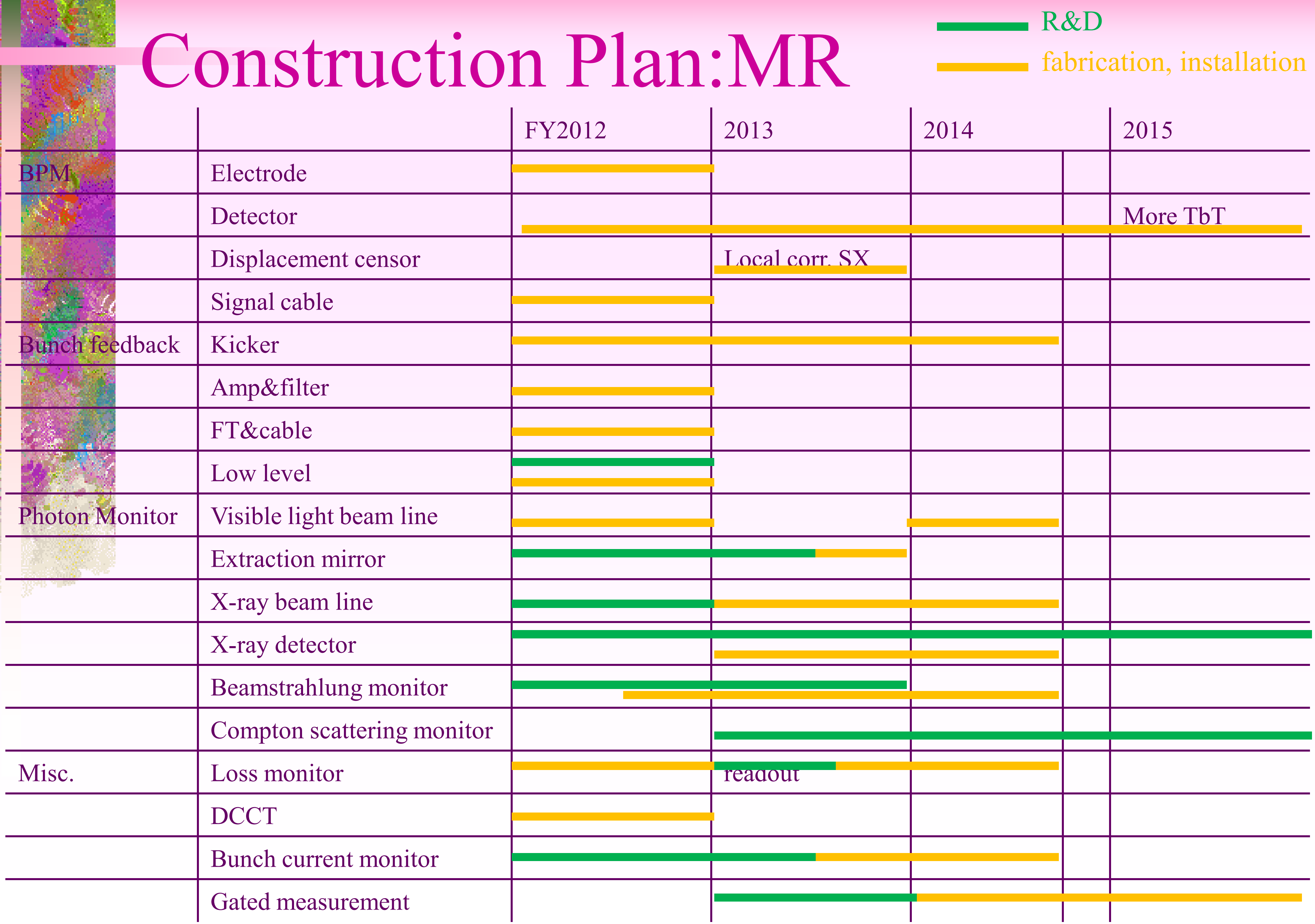
Loss Monitor

- Re-use the sensors (ion chamber and PIN PD) of KEKB.
- Because of recent results of beam loss simulation, we are studying whether the dynamic range of readout is sufficient or not, and will redesign it if necessary.
  - R&D: next FY
  - Production: FY2014
- If we increase the number of channels, extra cabling is necessary.

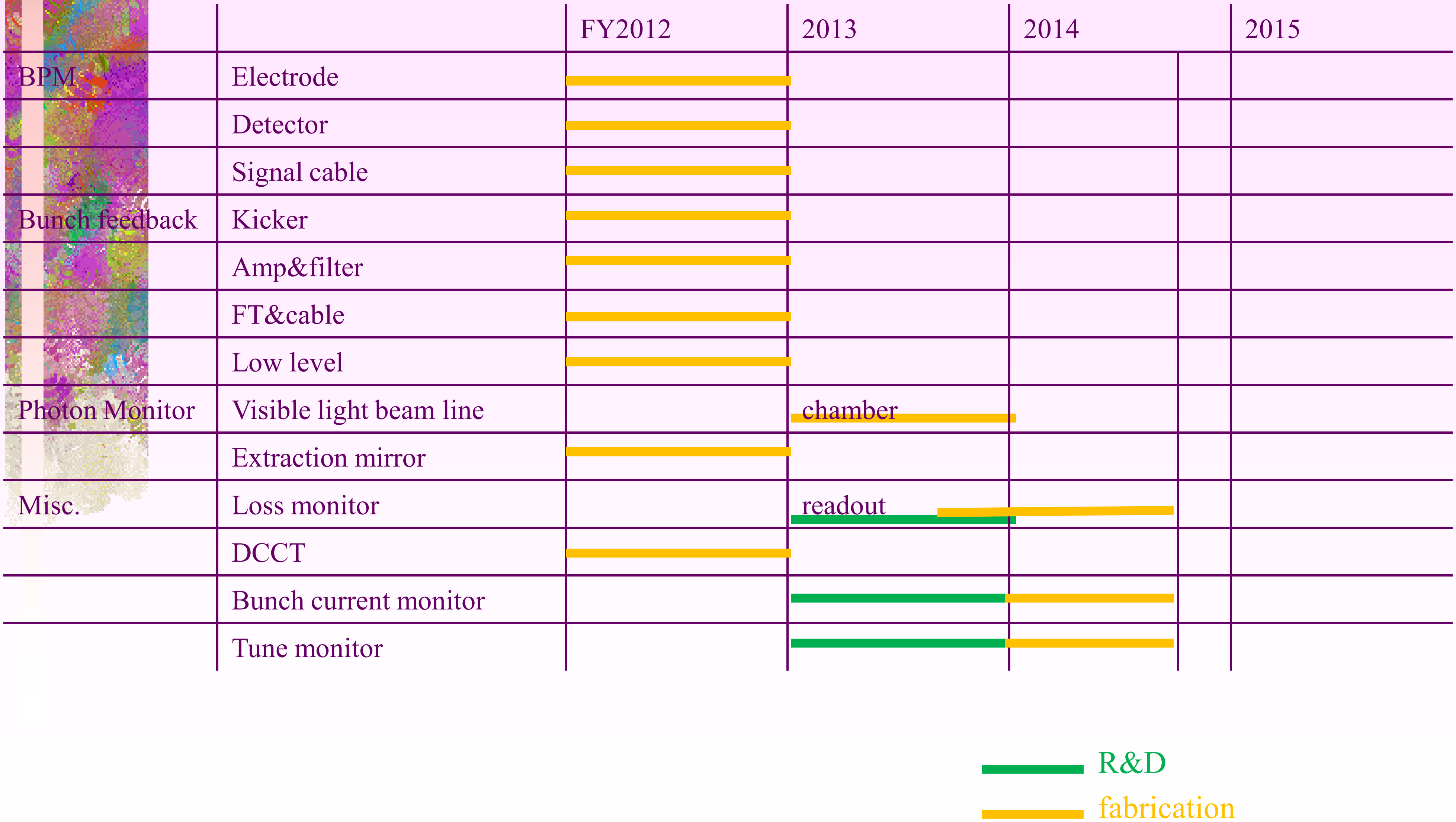
DR Monitor

- BPM
  - Electrode, Detector, Signal cable: ready
- FB
  - Kicker, Amp&filter, FT&cable, Low level: ready
- SRM
  - Extraction mirror, transport line, streak camera, gated camera and optical elements: ready
  - extraction mirror chamber : need to consult with vacuum group
- DCCT
  - Remodeling in progress
- Loss Monitor
  - Sensor: Reuse the linac ion chambers
  - Read-out: FY2014
  - Cables: ready
- Control rack, VME rack, NIM BIN etc. : ready

Construction Plan:MR



Construction Plan:DR



Summary

- Upgrade of beam diagnostics system is advancing smoothly. The installation schedule depends on other components. The tuning of each detector will be done.
- BPM
  - Electrode: ready
  - Narrowband detector: production in next FY
  - TbT: production in next FY and after
  - Mediumband detector: order/fabrication in next FY
  - Displacement sensor at local chromaticity correction section: design and fabrication in next FY
- FB
  - Most hardware is ready.
  - Longitudinal kicker and special monitor (pilot bunch excitation, gated measurement): production in next FY.

- Photon Monitors
  - SRM: testing the final extraction mirror and design chamber .
  - XRM: continue the testing of electronics, detector and construction of beam line.
  - LABM: continue the readout system and construction of optics box and extraction mirror.
  - CSM: future plan
- DCCT/CT: ready
- LM: studying specifications of readout electronics
- DR
  - R&D of LM readout, BCM and Tune meter
  - Installation time is restricted after DR construction.

Spares

X-ray monitor

Plans for 2013

- At Cornell:
  - Test Au+CVD (diamond) high-energy mask at CesrTA.
    - Imaging tests
    - Burn tests
  - Test new design of low-energy coded aperture (Cornell design) in 2013 at CesrTA.
  - Continue systematics studies of x-ray optics at CesrTA, and continue using coded aperture optics for electron-cloud and IBS studies.
- At UH:
  - Complete fabrication of redesigned 64-channel readout system for SuperKEKB.
  - Test 64-channel readout system at UH XFEL and ATF2.
- At SLAC:
  - Develop new high-energy detector for increased detection efficiency over SuperKEKB's x-ray spectral range.

SRM: Extraction mirrors

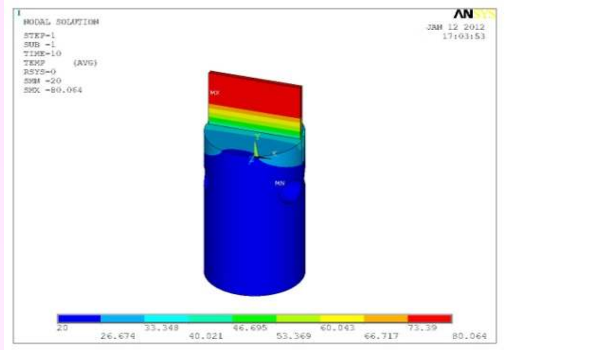
- Large incident power a source of heat-load induced deformations
- SuperKEKB LER source bend is recycled arc bend, with bending radius twice that of KEKB source bend.
  - Incident power becomes less than that of the KEKB HER, though more than that of the KEKB LER.
- HER bend does not change, and incident power becomes a bit higher than that of the KEKB HER.

	LER (BSWFRP)		HER (BSWOLE)	
	SuperKEKB	**KEKB**	**SuperKEKB**	**KEKB**
Energy(GeV)	4	3.5	7	8
Current(A)	3.6	2	2.6	1.4
Bending radius(m)	177.4	85.7	580	580
Power(W/mrad)	72	48	149	136
Distance to mirror (m)	11	11	13	13
Be Mirror width (mm)	35	35	35	35
Total incident power(W)	161	109	283	260

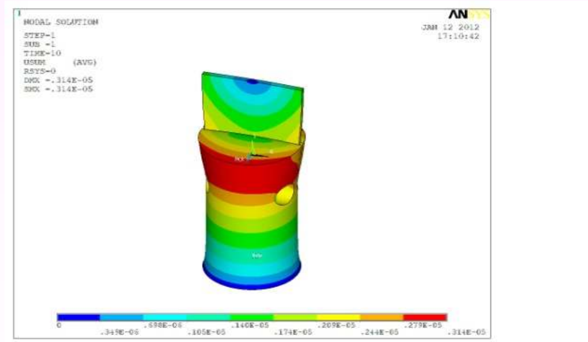
The heat deformation was already a great problem at KEKB, so would like to have a mirror that does not deform as much under the same heat load: diamond mirrors.

SRM: Diamond Mirrors

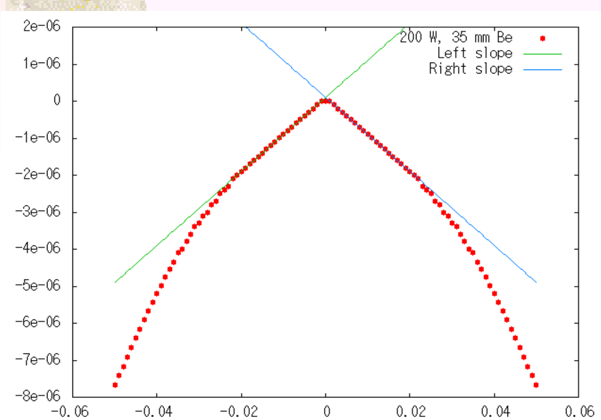
- Monocrystalline diamond:
  - Being developed by Seki Technotron
    - 10 mm x 20 mm x 0.5 mm prototype completed.
    - 20 mm x 20 mm x 1 mm prototype in fabrication
  - Surface: 3 μm Au, with thin Cr layer below that.
  - Diamond surface is (nearly) a single crystal, so good surface flatness expected (Ra ~ 2 nm, <~λ/50)
  - Very good heat conductance and low thermal expansion coefficient makes apparent change in magnification smaller than that of Be mirrors used at KEKB:
    - Berylllium: δmagnification = 43% @ HER full current
    - Diamond: δmagnification = 3% @ HER full current



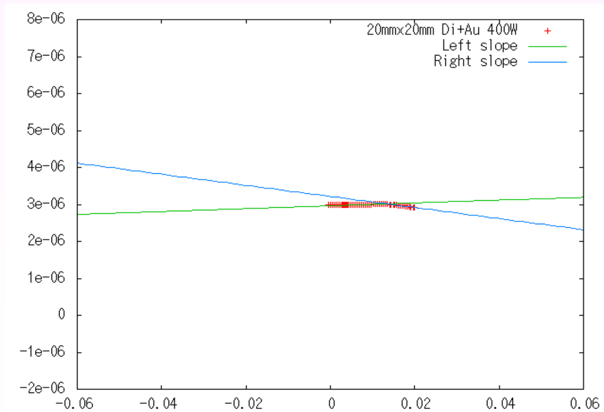
Diamond mirror temperature distribution due to 400W of SR power



Diamond mirror surface distortion due to 400W of SR power



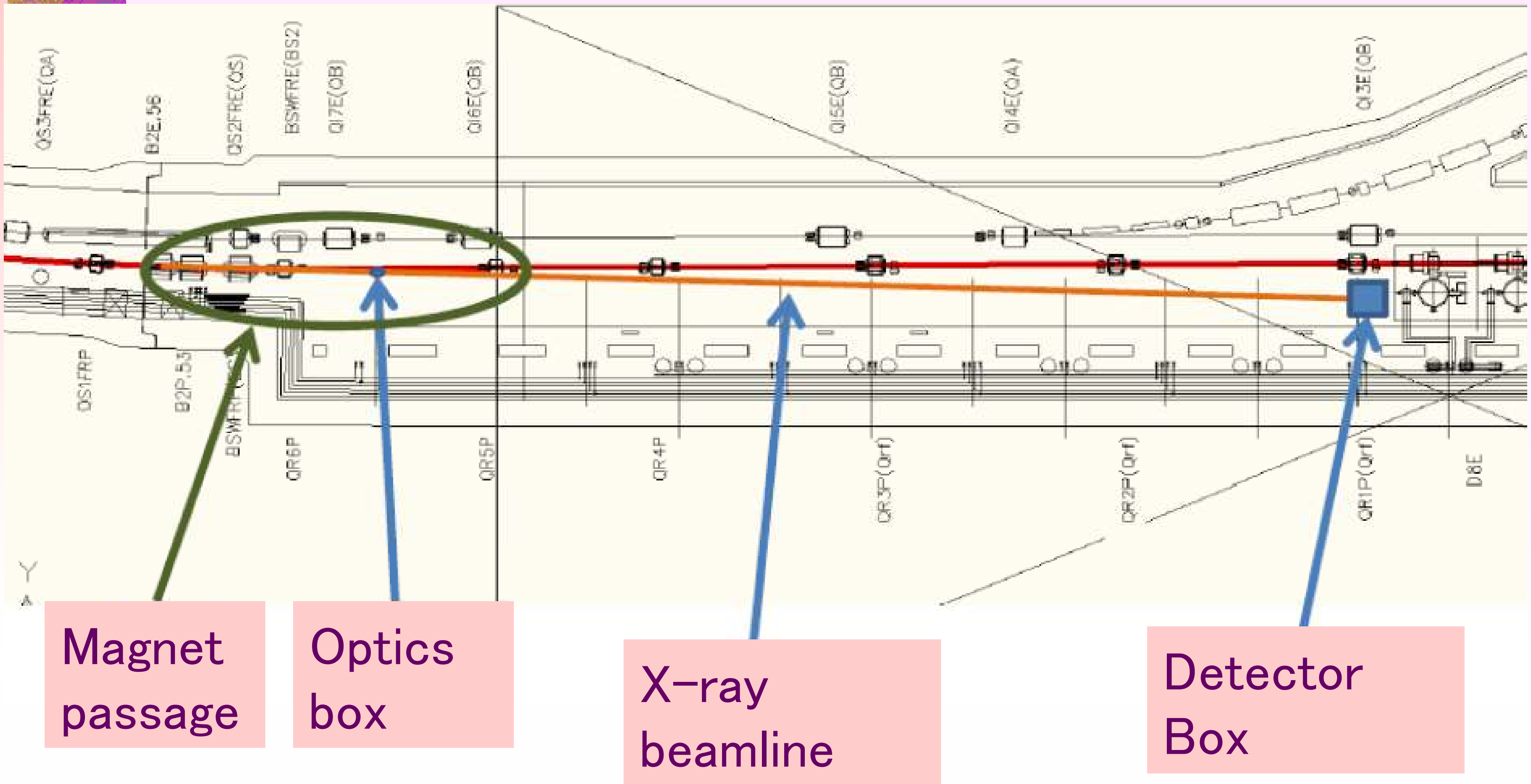
Mirror surface distortion due to 200W of SR power at center of Be mirror



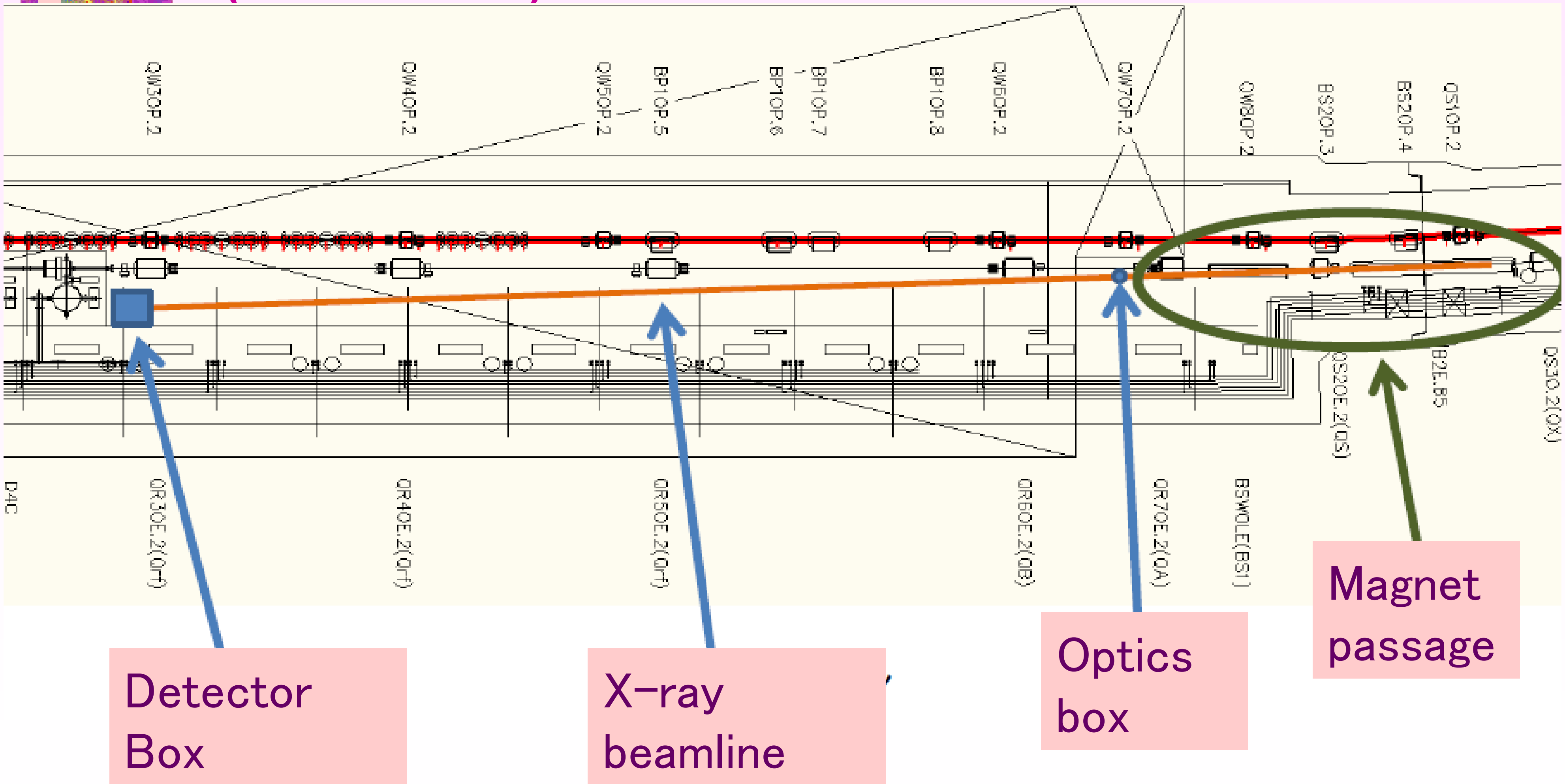
Mirror surface distortion due to 400W of SR power at center of Au+Dia mirror

ANSYS simulations: M. Arinaga

XRM: LER X-ray beamline (Fuji D8)



XRM: HER X-ray monitor beamline (Oho D4)

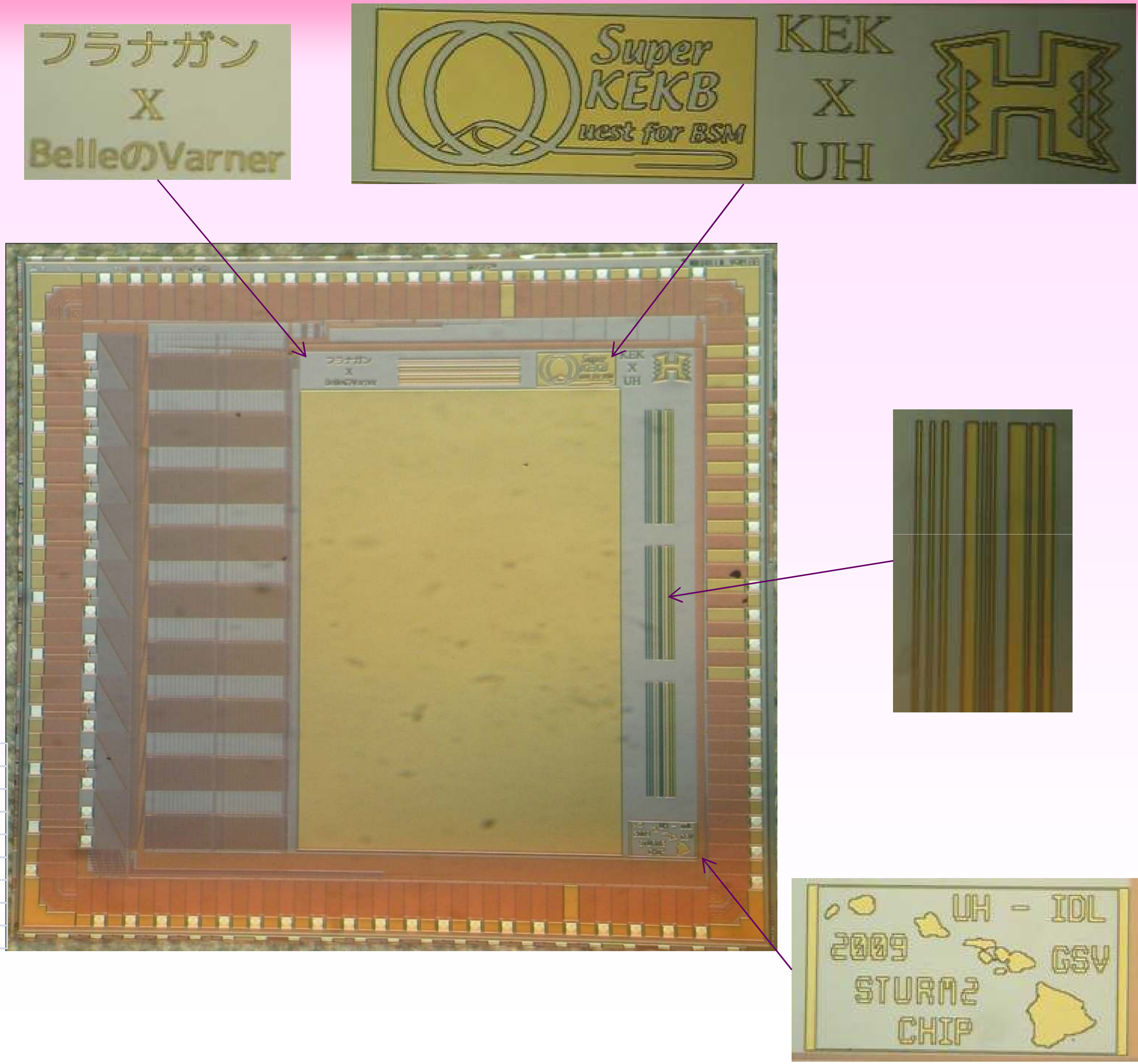


XRM: Digitizer

STURM2 ASIC

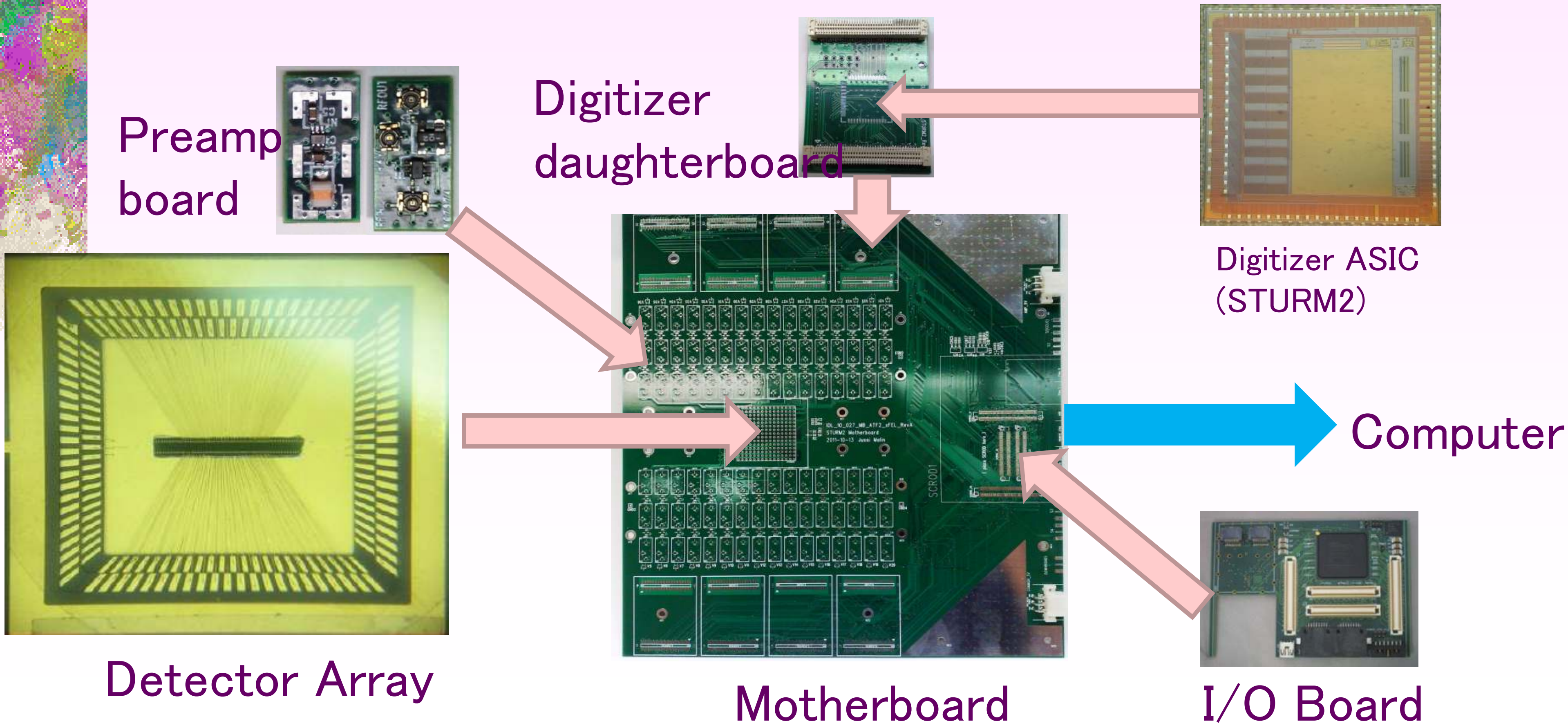
STURM ASIC for high-speed readout (G. Varner).
Ver. 1 tested at KEK PF, March 2009.
Ver. 2 fabricated.
Ver. 2 specs:

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)



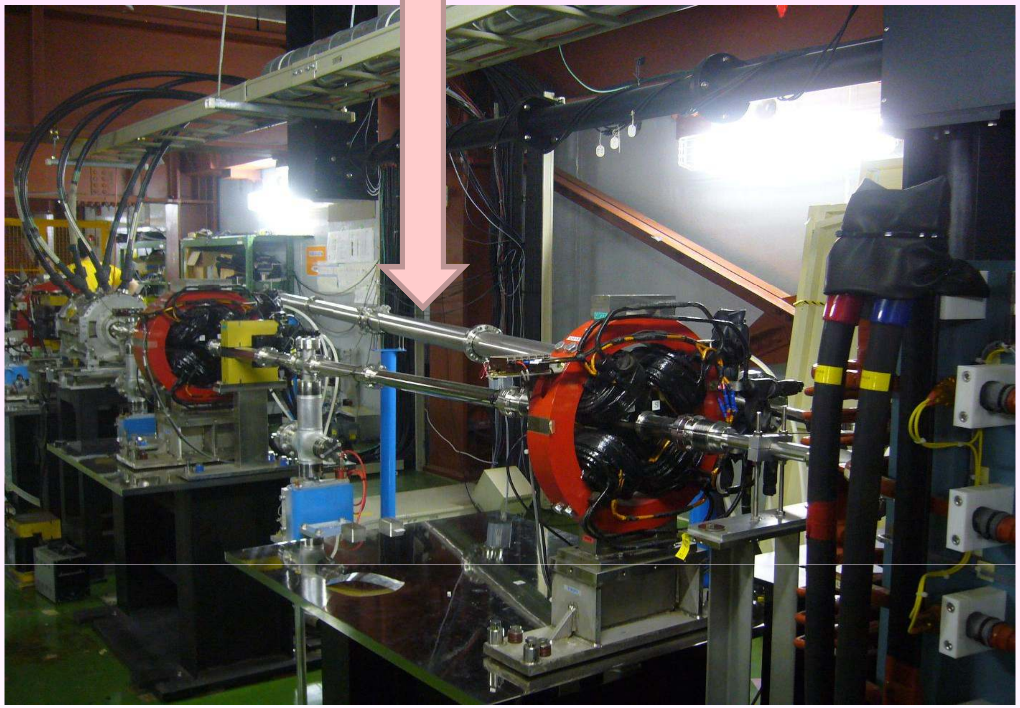
XRM: 64-channel system

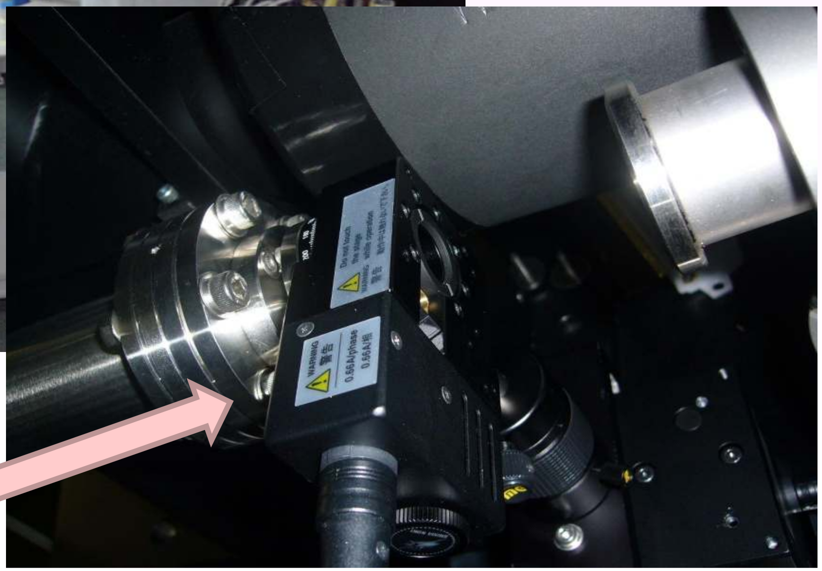
- 64-channel system for testing at ATF2
  - Using Fermionics (low-energy) detector.



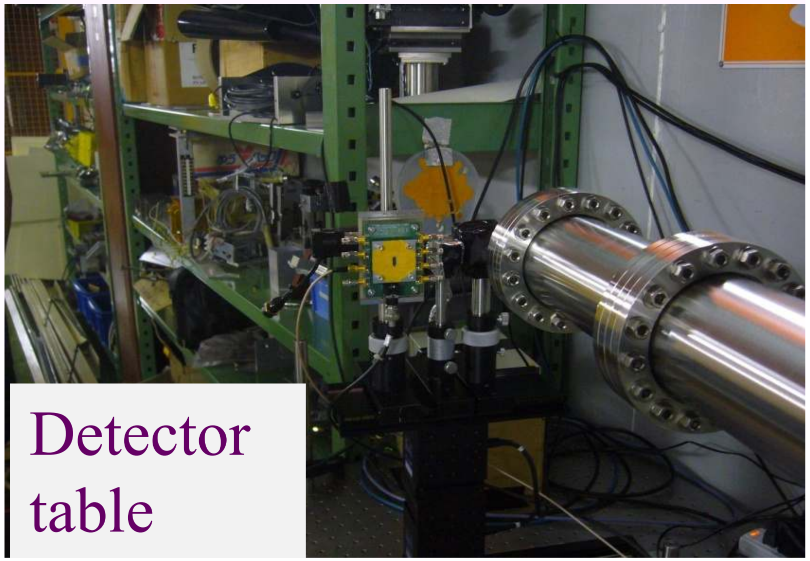
ATF2 x-ray beamline

During construction





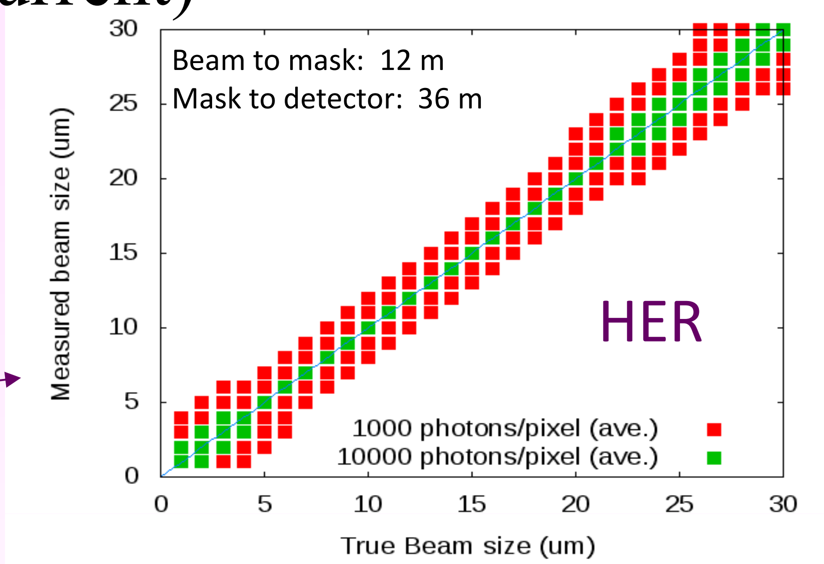
Rotating mask holder

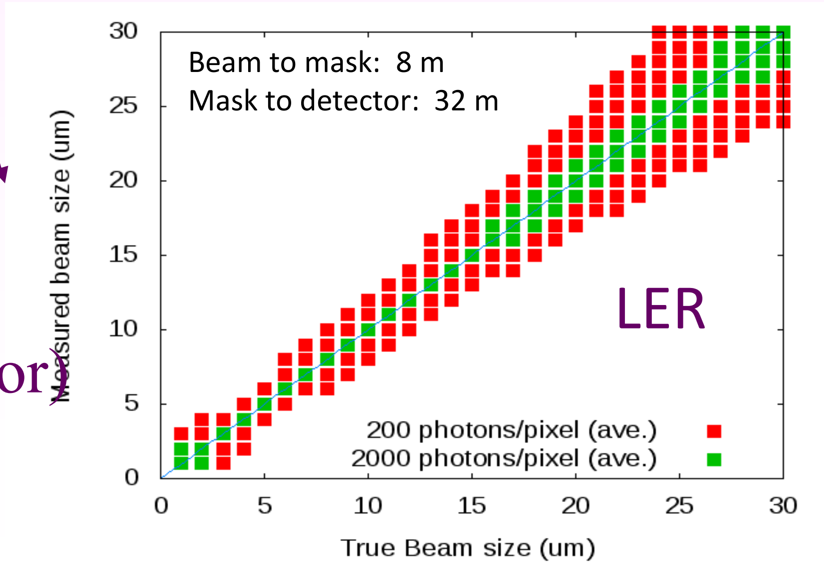


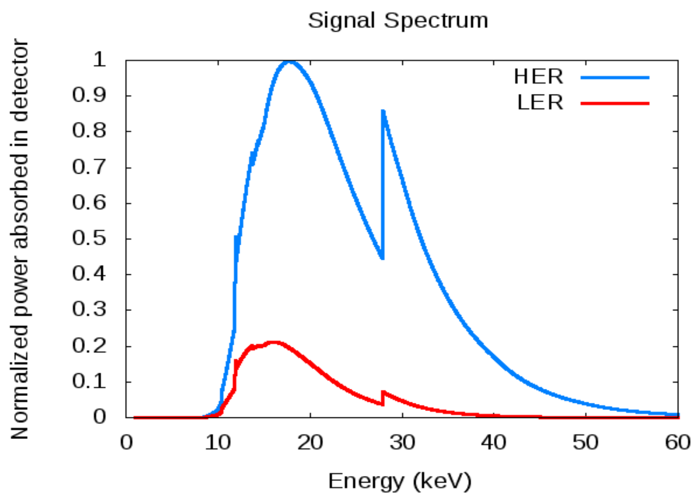
Detector table

XRM: SuperKEKB estimated single-shot resolutions (SuperKEKB full current)

- Red points: using 64-pixel detector of same type as at CesrTA (Fermionics)
- Green points: using detector with improved photon detection efficiency at higher x-ray energies (to be developed)







Detected spectrum (Fermionics detector)

XRM: Detector

- Tests with Fermionics detector at Photon Factory showed that detection efficiency at high energies is very low
  - Active pixel depth is only 3.5 microns.
- Detector development needed for the future
  - Higher efficiency at hard x-ray spectrum seen at SuperKEKB
  - Faster response for being able to directly diagnose head-tail instabilities at SuperKEKB.
  - Trench diode design being pursued:
    - Deep but narrow pixels
    - First prototype fabricated at SLAC
    - Detector development to continue