Collision feedback

OKI, Toshiyuki
on behalf of the working group

2014/MAR/3rd
19th KEKB Accelerator Review Committee

Introduction

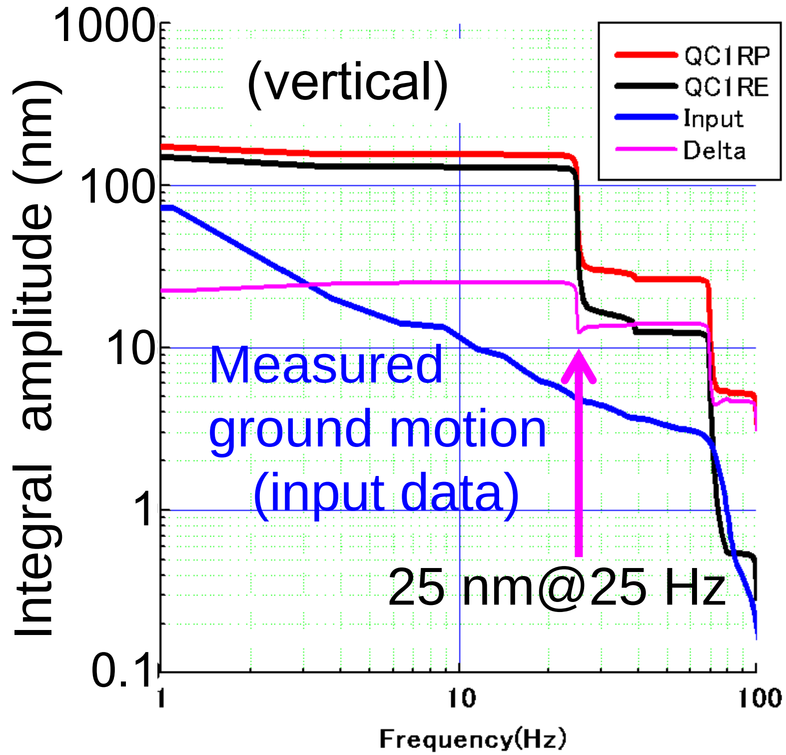
	SuperKEKB	KEKB
ε_y	~8.6pm (LER)	150pm
β_y^*	0.27mm(LER)	5.9mm
σ_y^*	48nm	940nm

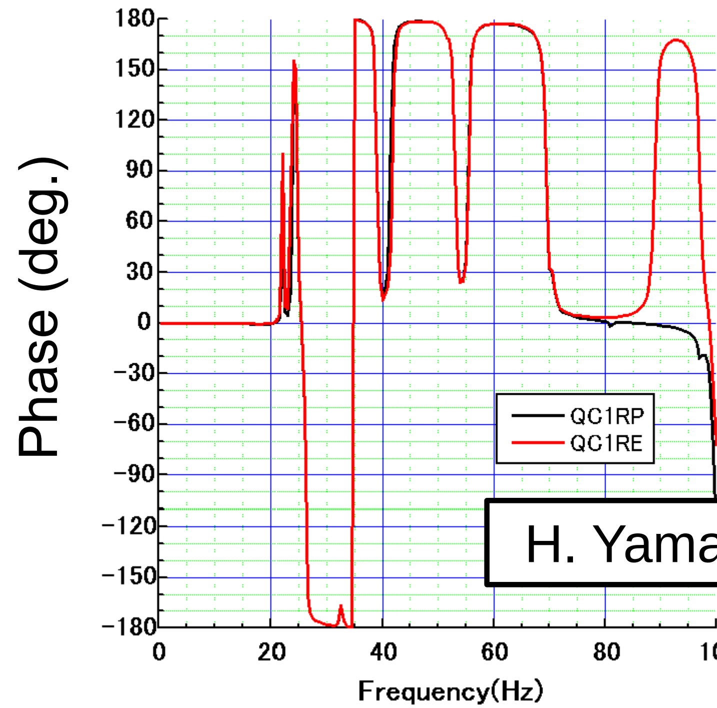
The beam size is 20 times smaller than one of KEKB.

How to collide beams successfully is much more difficult than KEKB.

High luminosity machine can be spoiled by the small vibration of QCS (QC1, QC2) caused by ground motion, even if it didn’t affect KEKB.

Estimation of QCS vibration and luminosity degradation





H. Yamaoka

QC1RP and QC1RE vibrate with same phase,
but the amplitude difference still arises: 25 nm at 25 Hz…

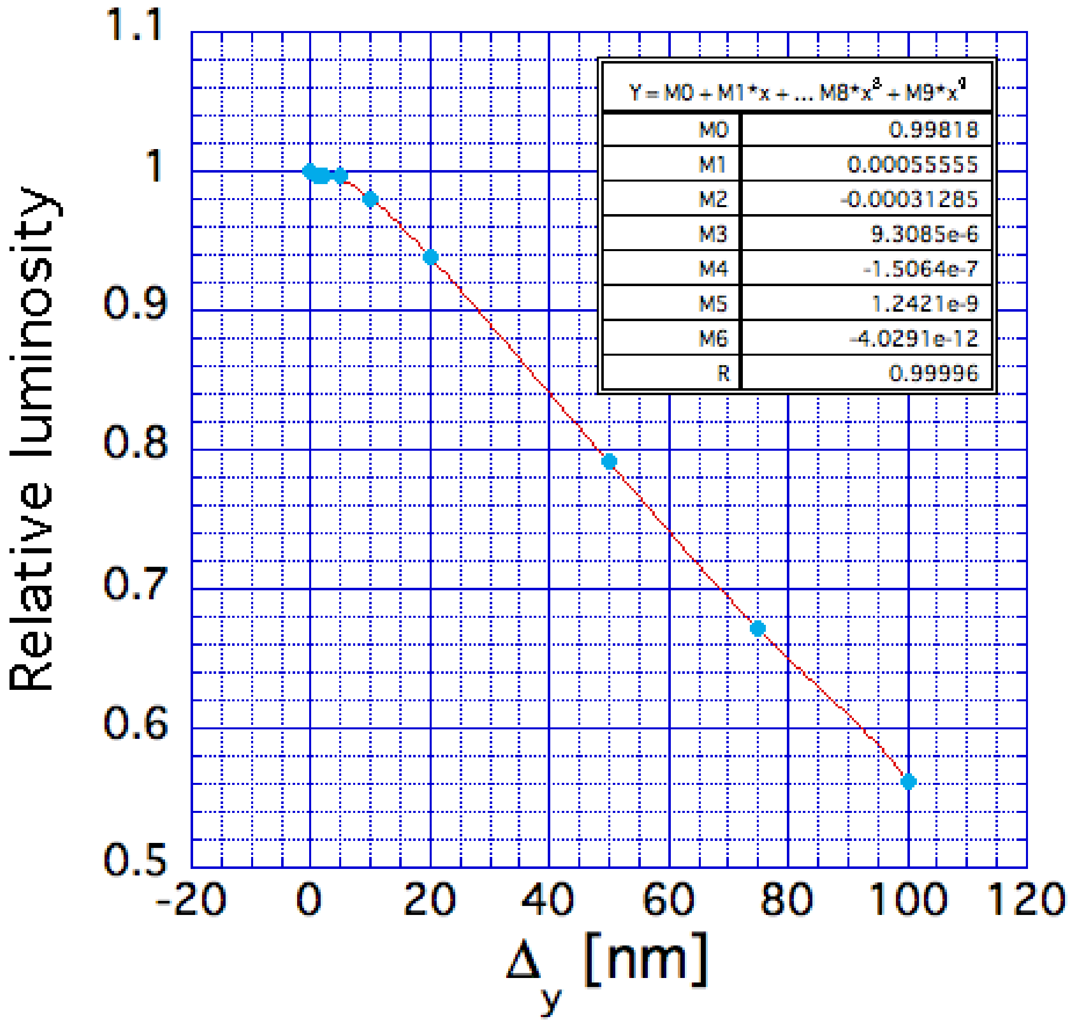
Luminosity degradation (based on beam-beam simulation by K. Ohmi)

Frequency (Hz)	24.85	38.93	69.34	99.60
Δy_{IP*}^{rms} (nm)	18.63	1.72	8.29	3.14
$L/L_0^{average}$ (%) in case of model-A (and F)	95.4 (96.1)	99.8 (99.8)	99.7 (99.8)	99.7 (99.8)

Y. Funakoshi

Beam-Beam simulation results

K. Ohmi

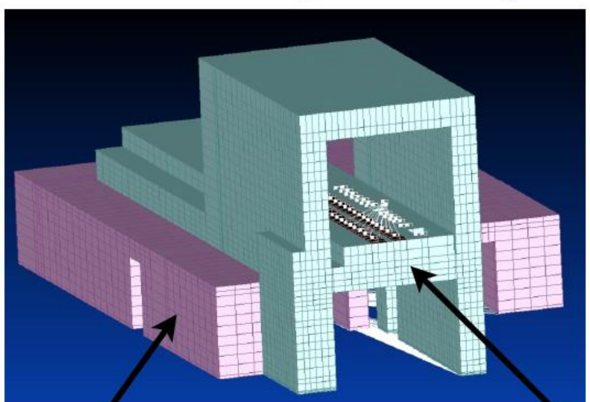


Just 20 nm offset leads to 6 % degradation of luminosity.

Reinforcement of bridge structure

H. Yamaoka

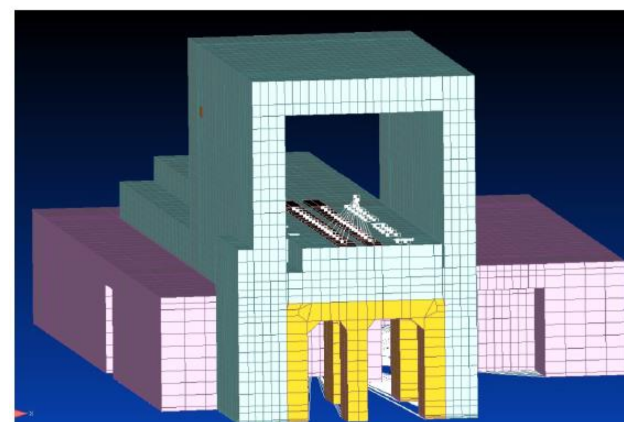
Model-A (baseline)



Entranceway is closed.

filling ditch

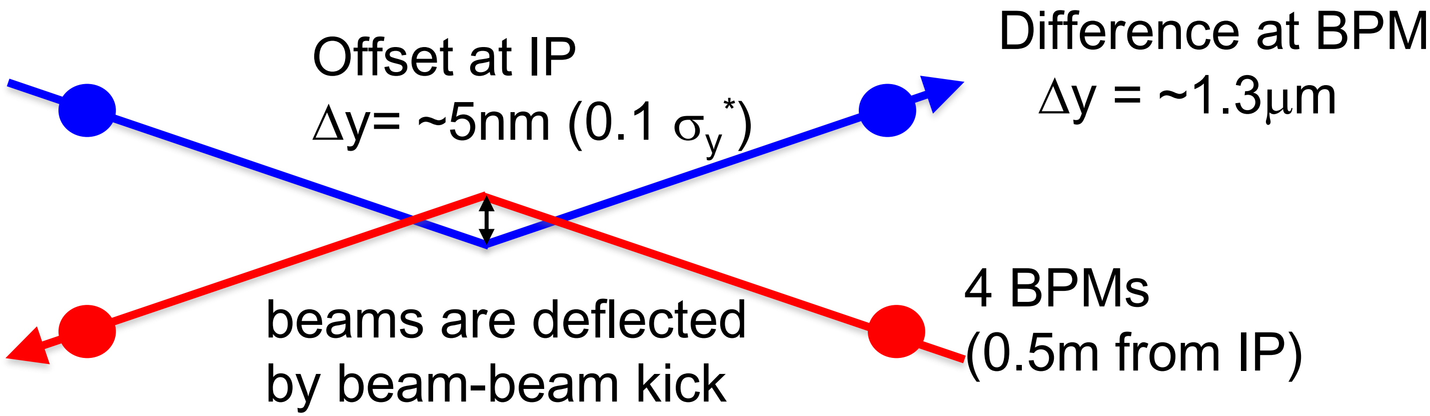
Model-F



Additional supports

Feedback scheme in vertical direction (y and y')

The orbital feedback system was used successfully for KEKB, which is based on beam-beam kick calculated from the BPM readouts at both sides of the IP.



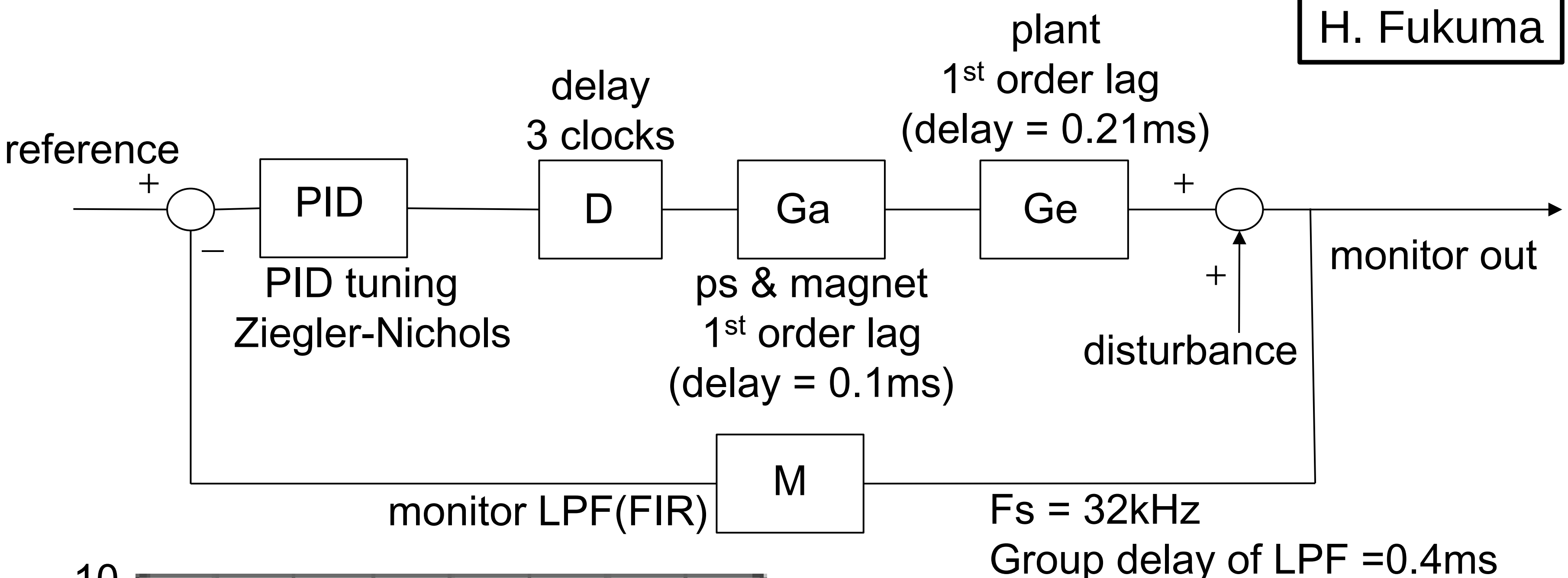
For SuperKEKB, It will be expected to work well.
The target resolution of BPM is the order of micrometer.

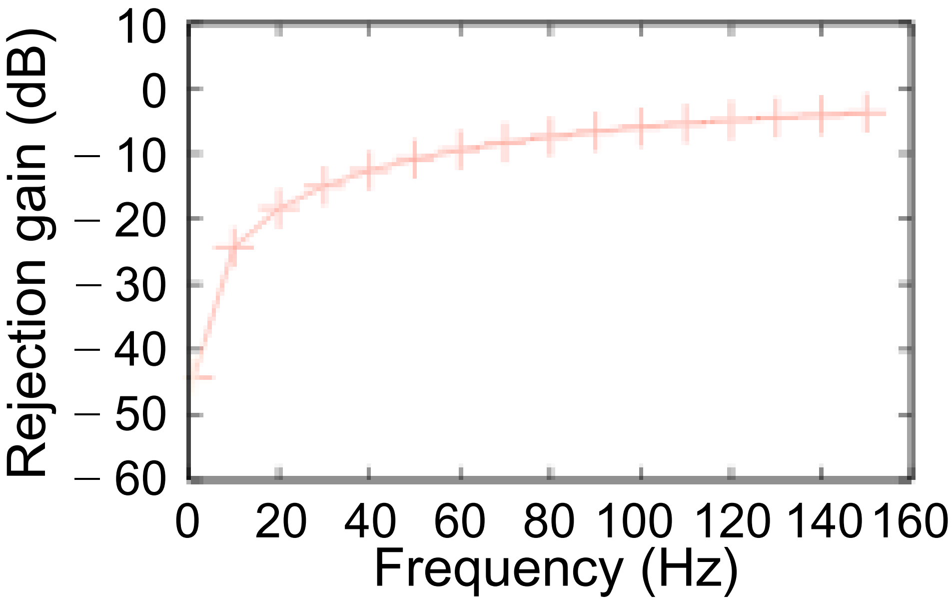
Prototype BPM was tested by using sinusoidal input signal.
0.1μm resolution has been obtained, successfully.

H. Fukuma

Rejection gain evaluation of the feedback system

H. Fukuma





Result shows
−16.7dB@25Hz is expected.

Amplitude of Δy_{IP*}^{rms} @25Hz will be reduced from 19 nm to 2.8 nm.

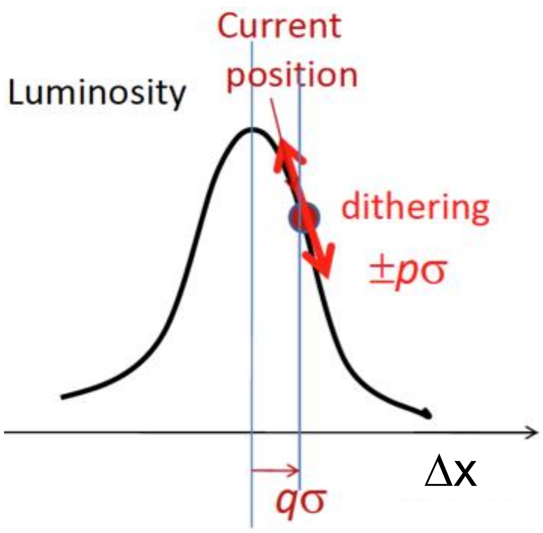
Feedback scheme in horizontal direction (x)

Beam-beam kick will not be a sensitive parameter for monitoring collision, as beam-beam parameter ξx is so small:

$$\xi x \sim 0.0028(e+),\ 0.0012(e-)$$
$$(\leftrightarrow \xi y \sim 0.0881(e+),\ 0.0807(e-))$$

Beams are not so much deflected in horizontal direction.

⇒The Luminosity dither is being considered, which was used for PEP-II successfully.



When two beams overlap, the luminosity drops on either side of the peak, giving modulation at $2\omega_{dith}$.

Off center, there is additional modulation at the fundamental.

Dithering simulation by U. Wienands and S.Uehara: Max. dithering amplitude, which corresponds to 10 % drop of the peak luminosity should be prepared.

Luminosity dither system for horizontal feedback (+ vertical offset and angle)

(1) Fast luminosity monitor (ZDLM): S. Uehara and P. Bambade.

(2) Electronics to discriminate dither signals:
Lock-in amplifiers and/or digital technic are considered.

(3) Beam pipes: made of stainless steel for magnetic field penetration.

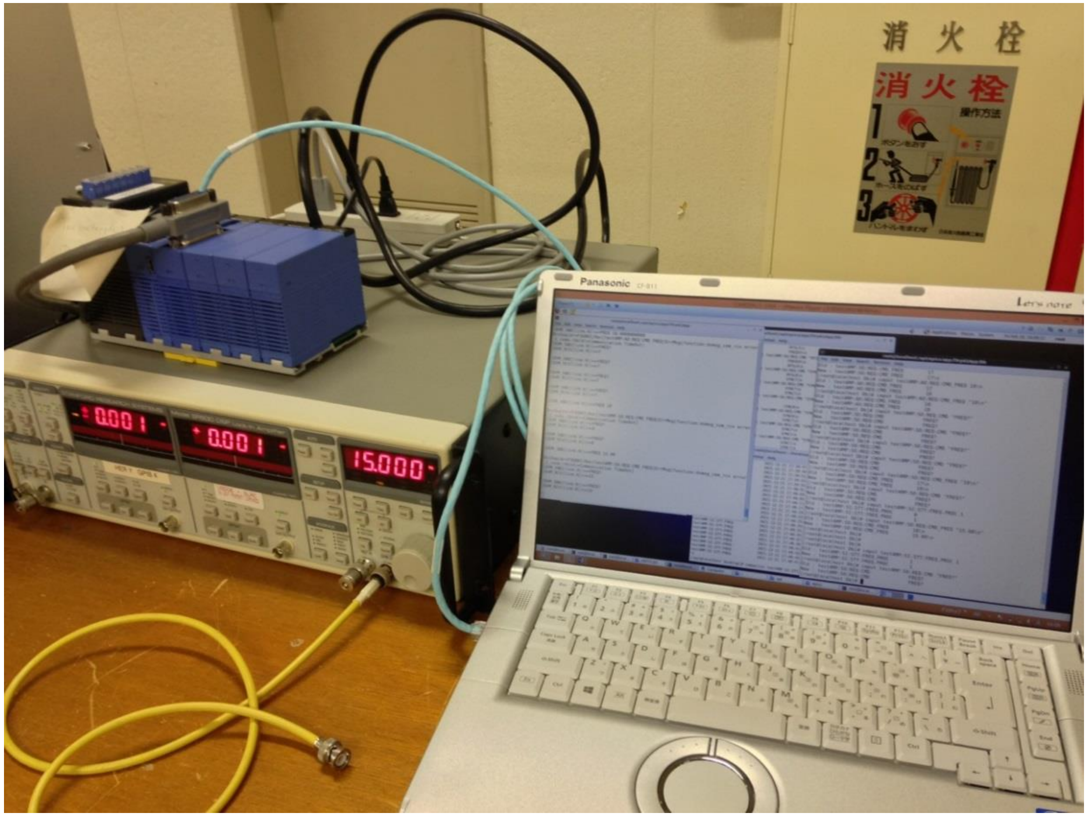
(4) Air-core dithering coils:
- Dithering coils will be installed into 8 locations.
- Dither frequency: 60~100 Hz is chosen to avoid power line interference.
- Kick angle of dither coils: to generate ±50 μm horiz. bump.
- Design work, production and field measurement are under way at SLAC.

(5) Power supplies for actuating coils: commercial bipoler PS (± 65 V, ± 5 A).

(6) Iron-core steering magnets at HER for orbit correction.

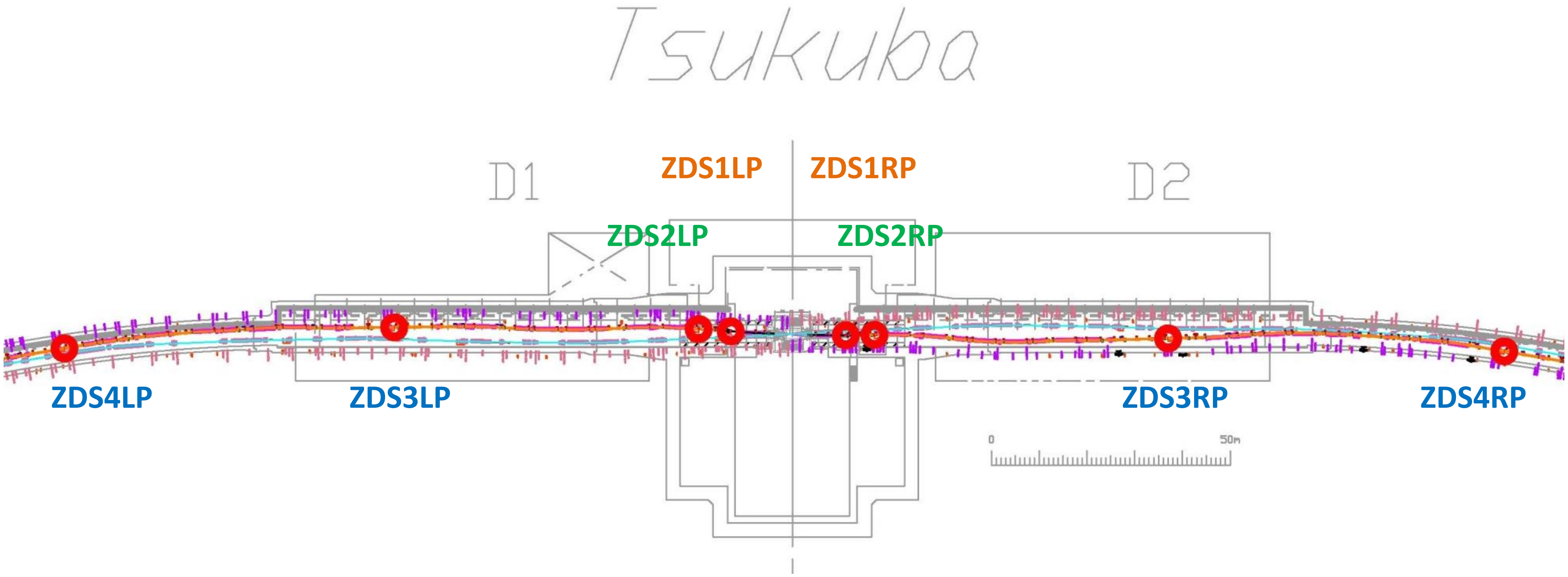
Lock-in amplifier: Stanford research systems model SR830

SLAC loaned us the Lock-in amp. last summer.
We have tried to use it with EPICS for a remote control.



Locations for the dithering coils

8 locations for the dithering coils in LER around IP.



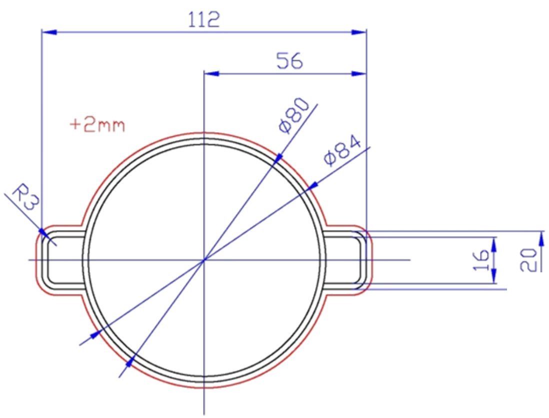
Designs for 3 type of beam pipes

Y. Suetsugu

ZDS1{L, R}P

Inner diameter: 80 mm

Thickness: 2 mm

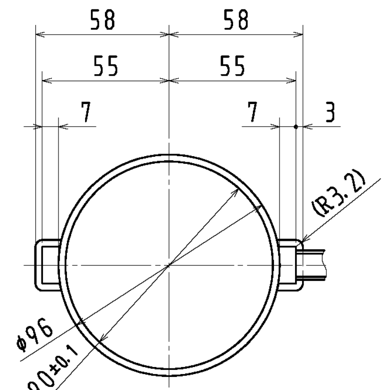


ZDS2{L, R}P

Inner diameter: 90 mm

Thickness: 3 mm

10 μm Cu coating inside.

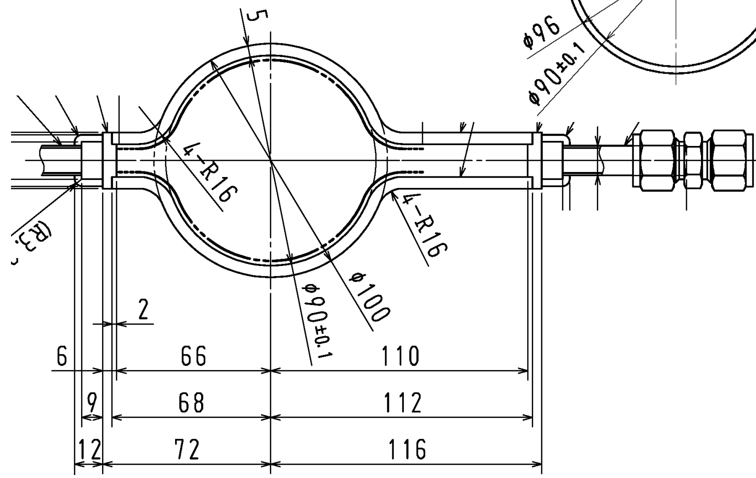


ZDS{3, 4}{L, R}P

Inner diameter: 90 mm

Thickness: 5 mm

10 μm Cu coating inside.



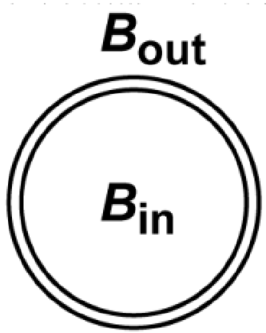
Pipes will be delivered to KEK by this March.

All pipes are made of SS316L.

Damping of magnetic field due to eddy current

Damping ratio

$$\frac{B_{in}}{B_{out}} = \frac{1}{\sqrt{1+(\omega\tau)^2}}$$



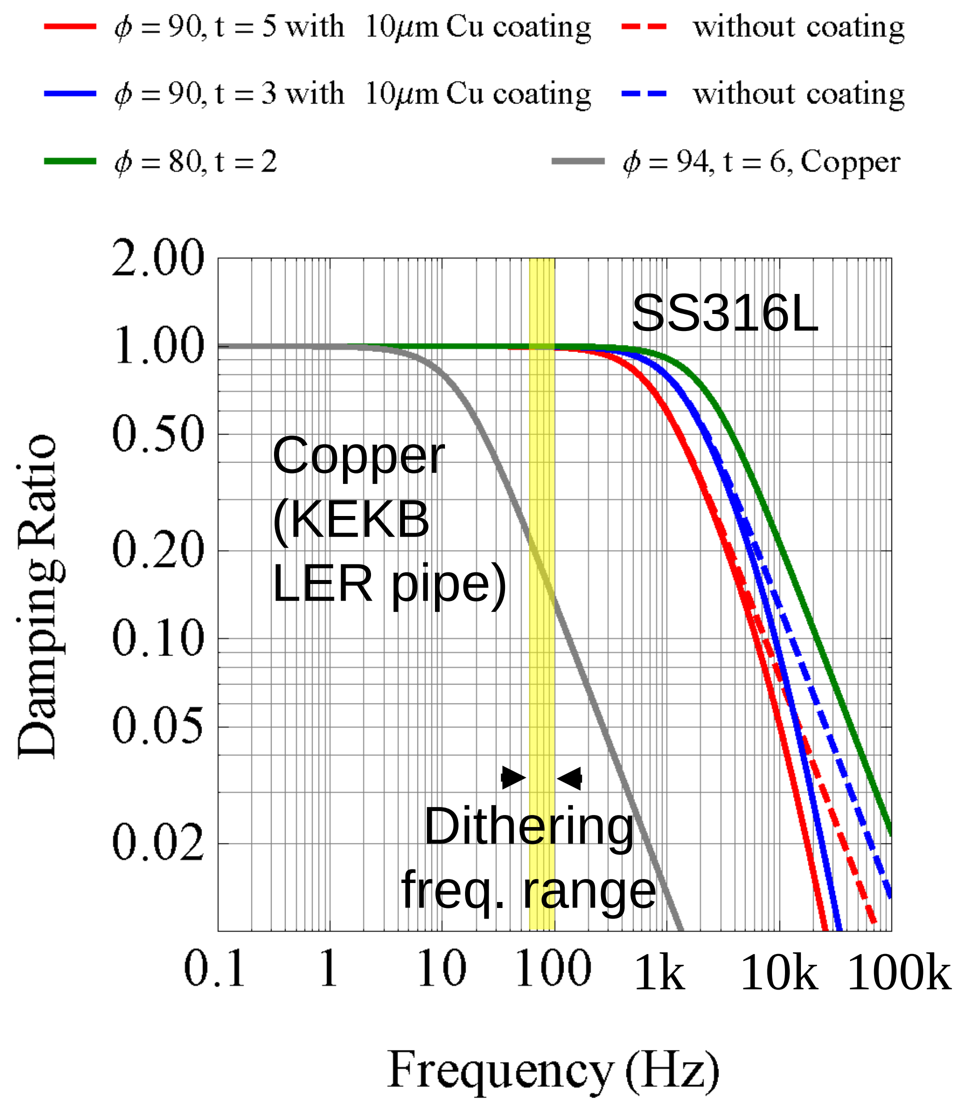
where: $\tau = \frac{\mu_0}{2}\frac{bt}{\rho}$,

b: outer radius (m),

t: thickness (m),

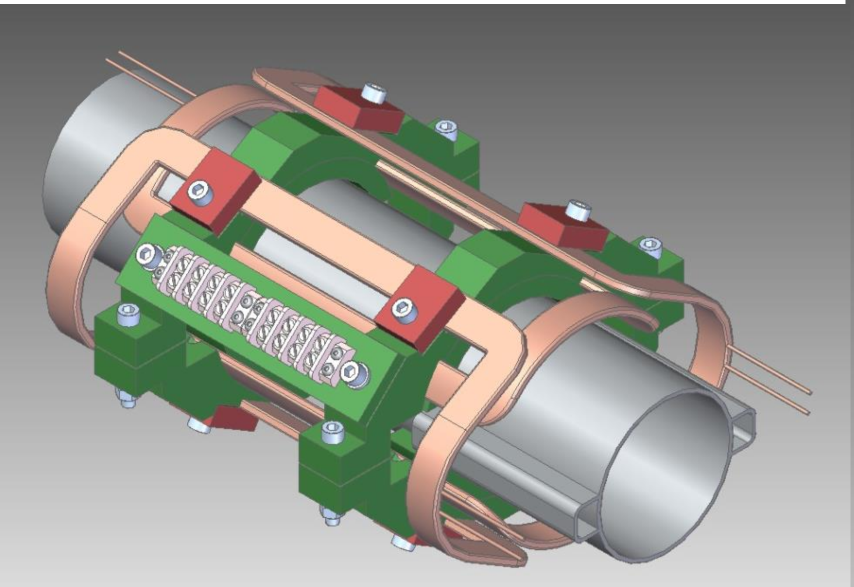
ρ: resistivity ($\Omega \cdot$m)

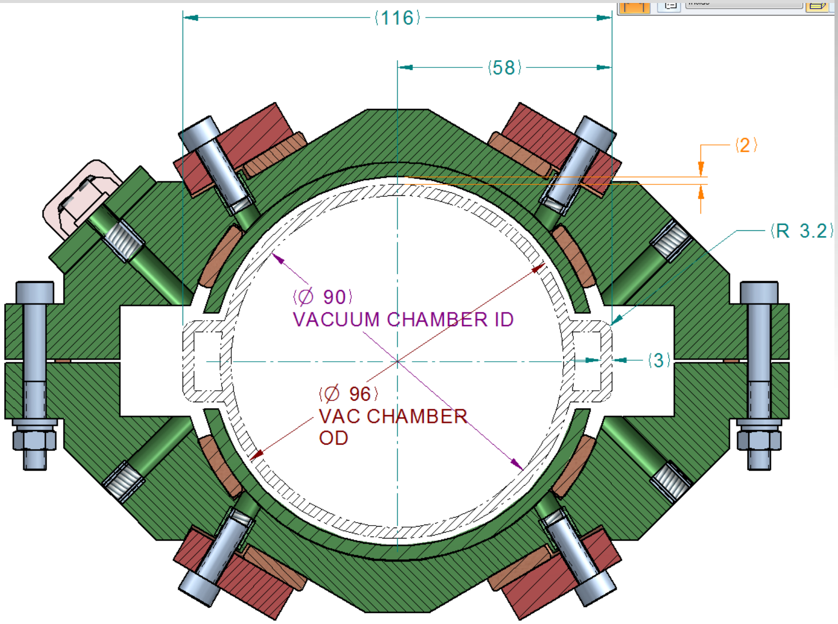
A.W. Chao and M. Tigner, Editors, Handbook of Accelerator Physics and Engineering, World Scientific, Singapore (1999), p. 268

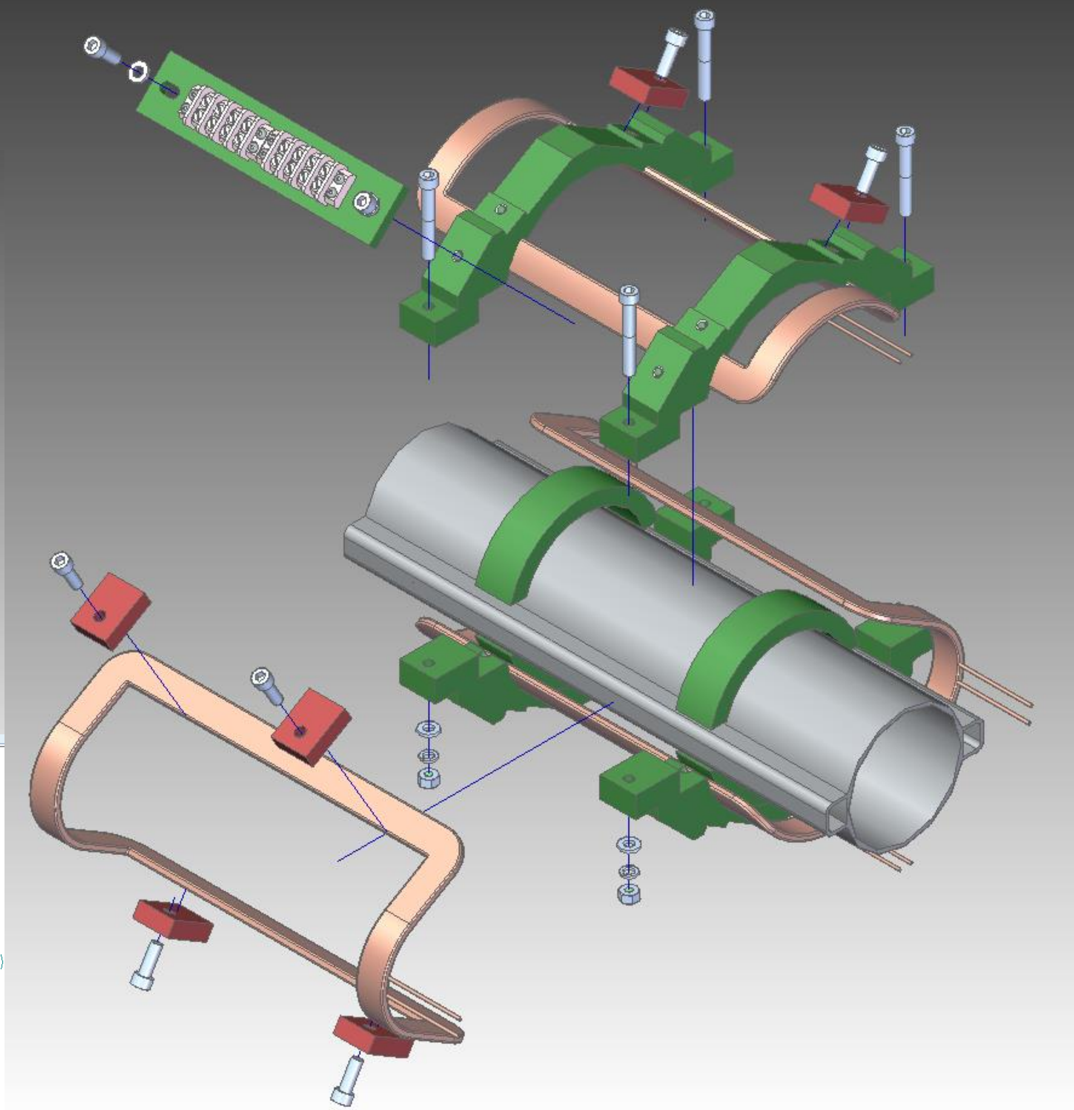


Resistive and thinner pipe suppresses the damping effect.

Coil mechanical design







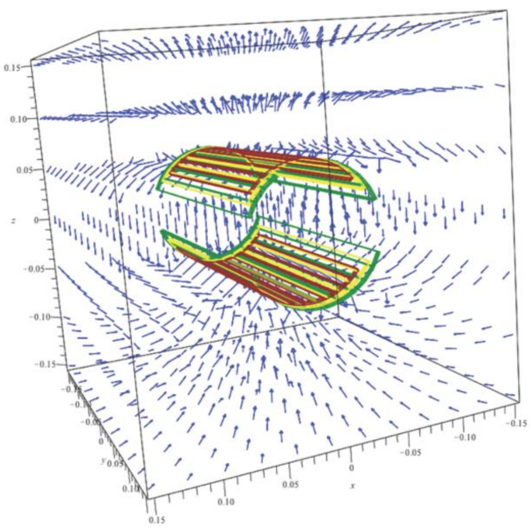
M. Kosovsky, SLAC

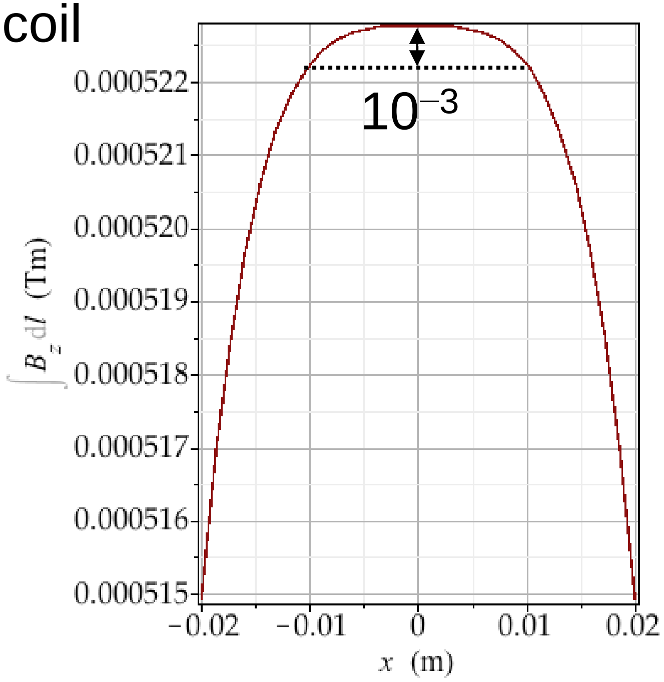
Coil field evaluation

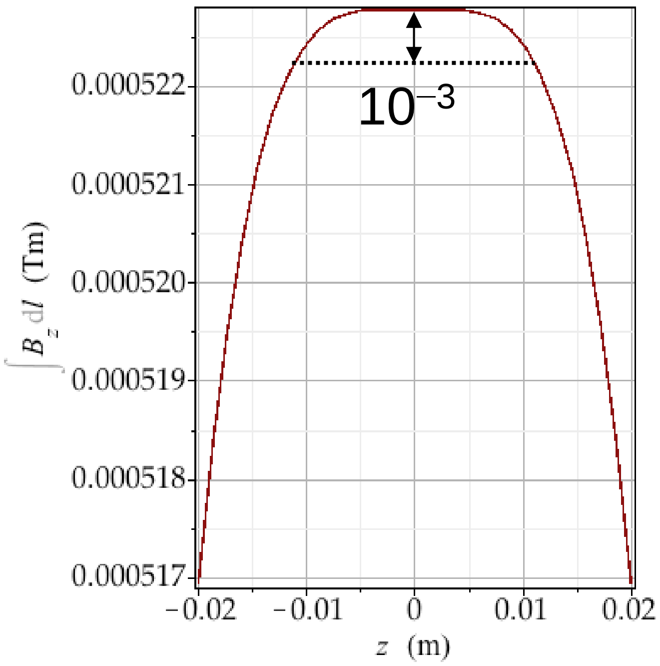
Calculations show that the field quality meets the requirements:
10 mm (15 σ_x + 2 mm) radius of good field region for dB/B < 10^{-3}

- verification of model using OPERA-3D was performed.
- Note: Effect of chamber eddy currents not included.

Example of horizontal coil







U. Wienands, SLAC

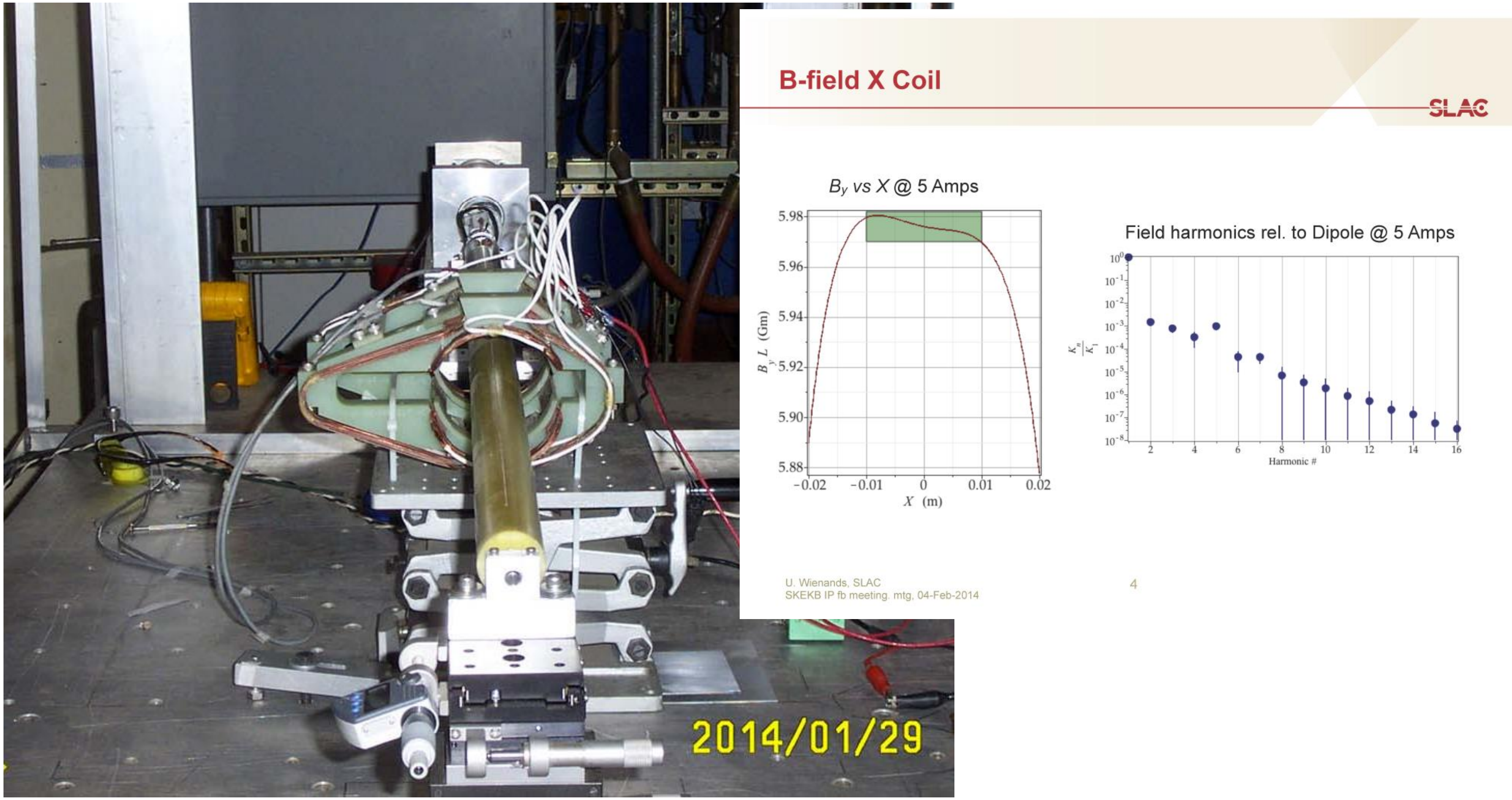
Coil parameter

ZDS1/2 horizontal coil, wide & layered model; dimensions refer to outer or inner limits															(per coil)				
Length	Length	Width	Radius	Radius	R chambr	subt angle	middle gap	Wire	Width	Layers	Height	Turns	Wirelength	∫Bdl	kick	Inductance	Voltage (ac)	Power (real)	dB/B max
(m)	(m)	(mm)	(mm)	(mm)	(mm)	(°)	(mm)	(# AWG)	(mm)		(mm)		(m)(1 coil)	(Gm)	(μrad)	(mH) (1 coil)	(V)(2 coils)	(W)	'(1E-3@1cm)
outer	center	outer	center	inner	outer	center													
0.243	0.225	138.8	56.0	54.1	51.0	118.9	20	16	18.1	3	3.8	38	26.0	5.2	39.2	0.9	6.7	8.6	1
ZDS1/2 vertical coils, wide model no layers, thickness for geometry only.																			
					X-coil outer														
0.243	0.225	155.7	65	63.1	0.0	119		16	18.1	3	3.8	38	28.9	4.5	34	1.1	7.7	9.5	0.6
ZDS3/4 vertical coils, wide model no layers, thickness for geometry only.																			
0.243	0.225	155.7	65	63.1	0.0	119		16	18.1	3	3.8	38	28.9	4.5	34	1.1	9.2	9.5	0.7
		271.5	65	63.1	0.0	118.6		16	18.1	3	3.8	38	37.7	4.5	34	1.5		12.4	
All values for 5 A, 100 Hz excitation, 4 GeV						Coil pancake			dimensions refer to center of pancake										

Resistance, inductance and power are within acceptable limits
(up to ~ 10 V, 13 W/coil (real peak power) at 5 A, 100 Hz)

U. Wienands, SLAC

Fabrication and field measurement



Fabrication and measurement of coils will be finished by this March.

U. Wienands, S.D. Anderson, MFD Metrology, SLAC

Summary

— It is challenging to collide small beams successfully.

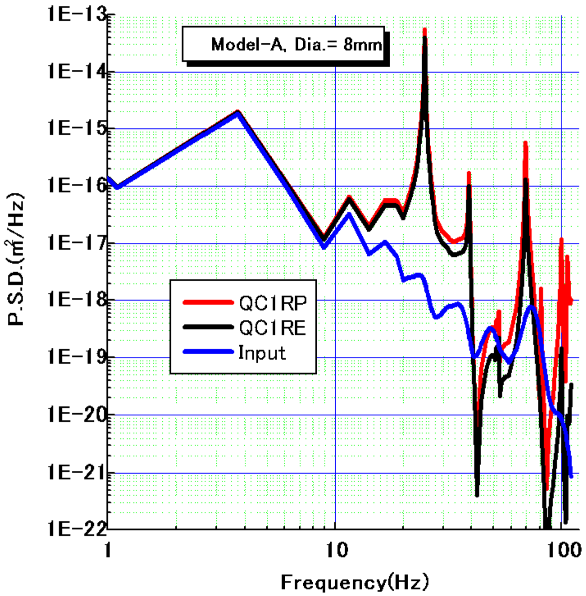
— For vertical offset and angle feedback:
Orbital feedback system is under consideration. It was used for KEKB and is based on beam-beam kick calculated from the BPM readouts at both sides of the IP.

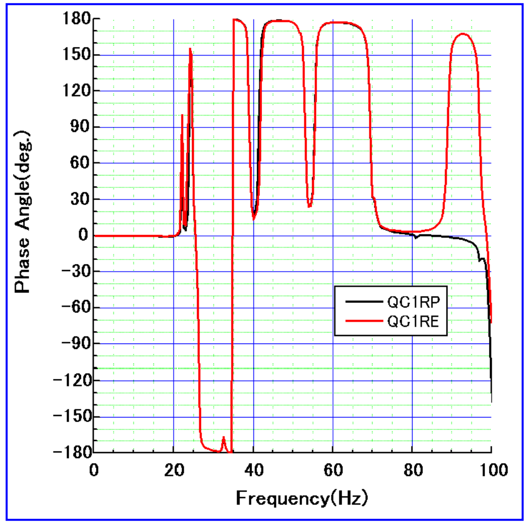
— For horizontal offset feedback:
Luminosity dither is being considered as used for PEP-II, because beam-beam kick will not be a sensitive parameter for monitoring collision due to small beam-beam parameter.

Appendix

Model-A

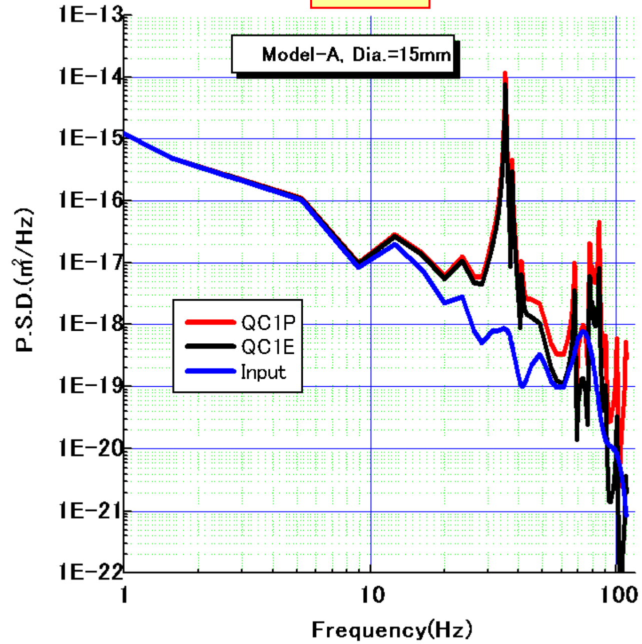
R側

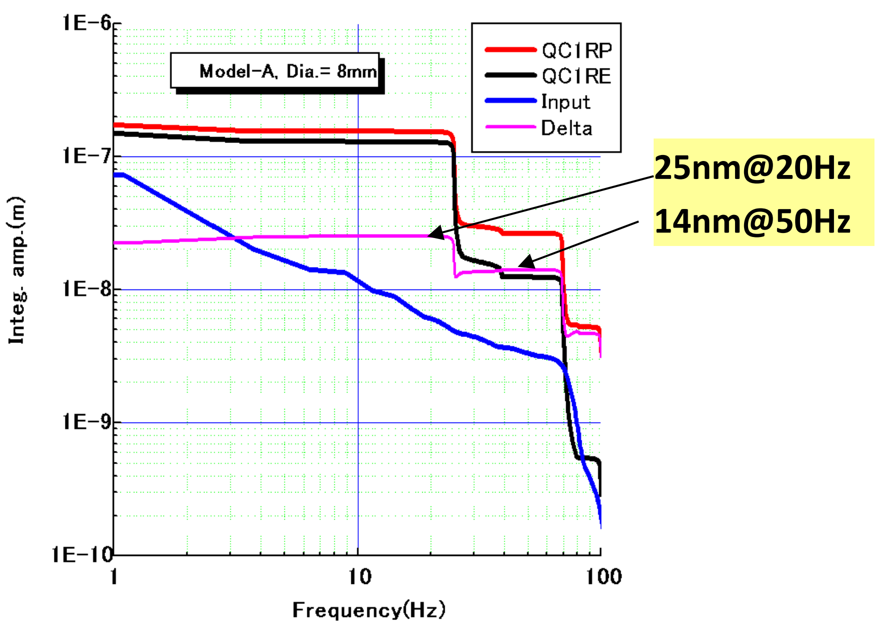


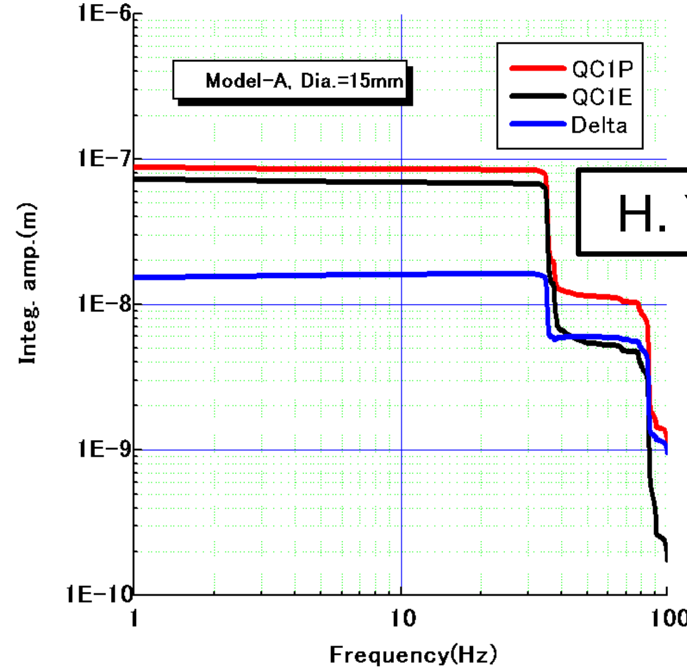


Oscillation phases of QC1RP and QC1RE.

L側



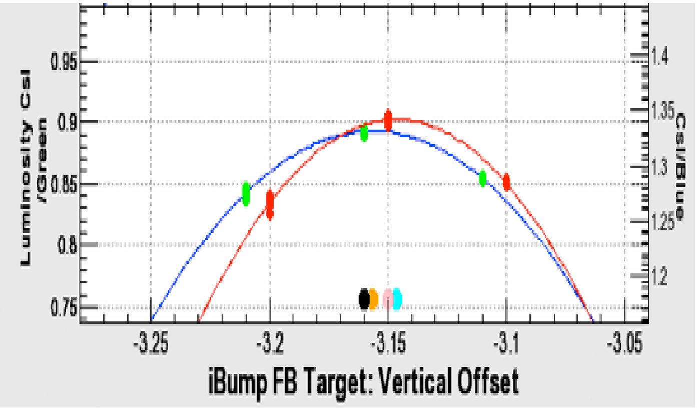




H. Yamaoka

山岡

Experience at KEKB

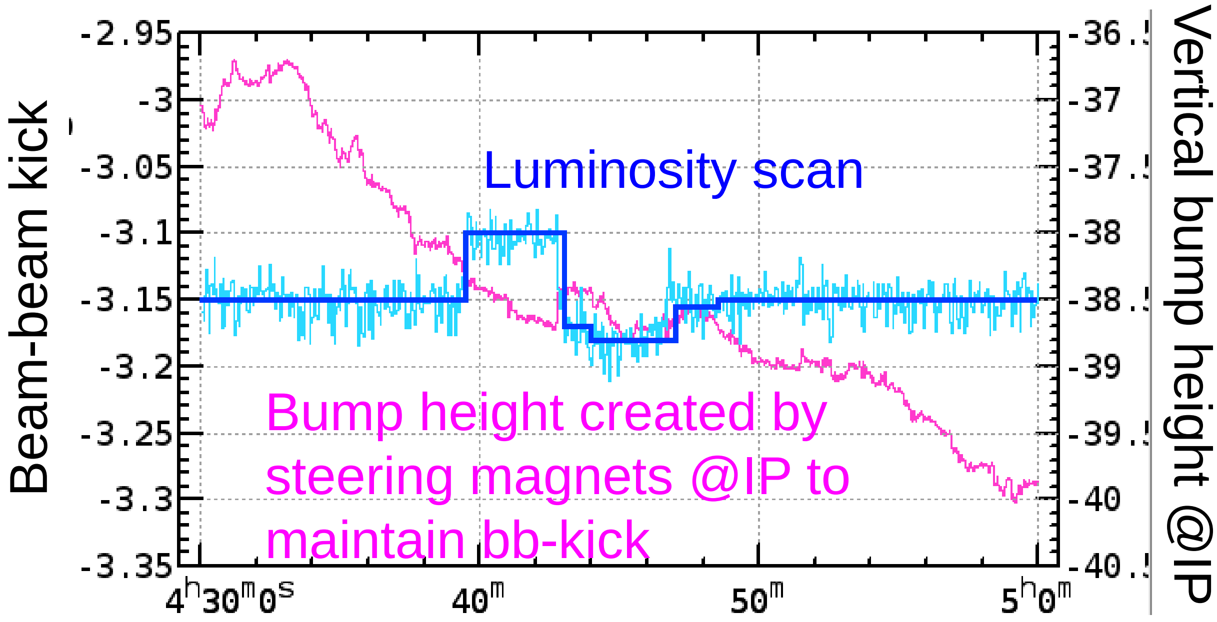


(1) Finding good collision

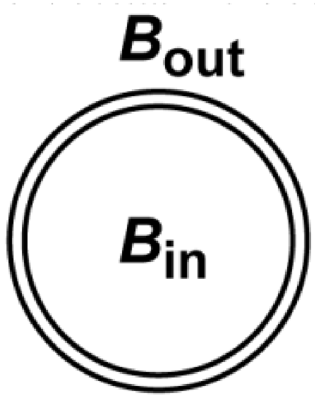
1. Calculate beam-beam kick (b-b deflection) using BPMs.
2. Change bb kick by changing setting of steering magnets located on either side of the IP.
3. Luminosity scan: Lumi. vs bb kick.

M. Masuzawa

(2) Maintaining good collision



Damping and phase delay of a magnetic field

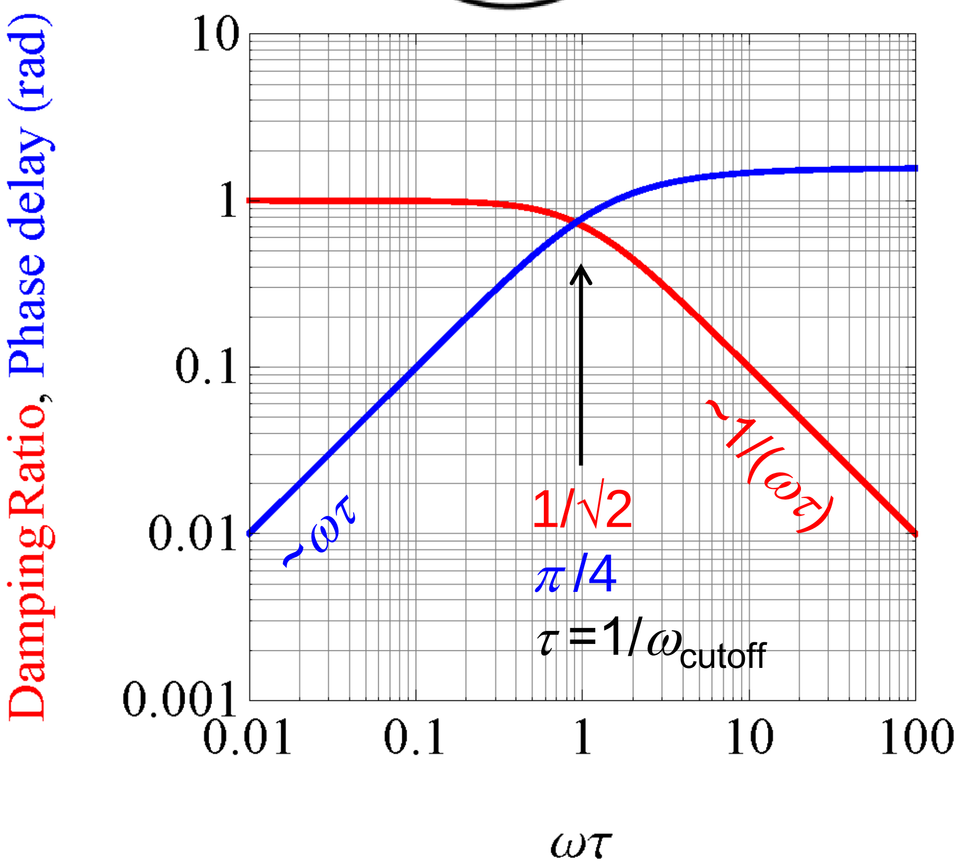


$$B_{\text{out}} = B_0 \sin(\omega t)$$

$$B_{\text{in}} = \frac{1}{\sqrt{1+(\omega\tau)^2}} B_0 \sin\left[\omega t - \arctan(\omega\tau)\right]$$

Damping ratio

Phase delay



where,

$$\tau = \frac{\mu_0}{2}\frac{bt}{\rho}$$

: ramping time for step response,

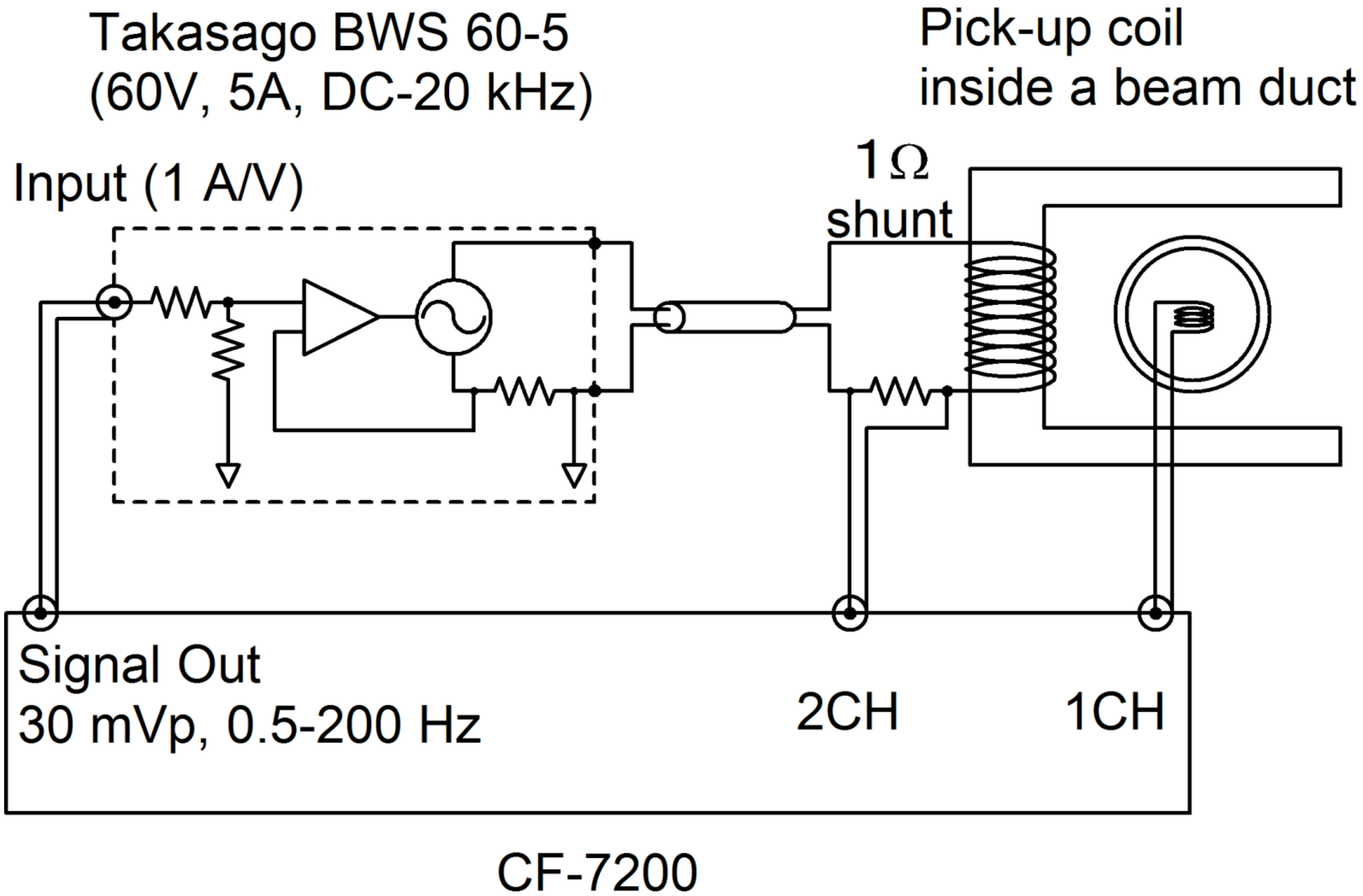
b: outer radius (m),

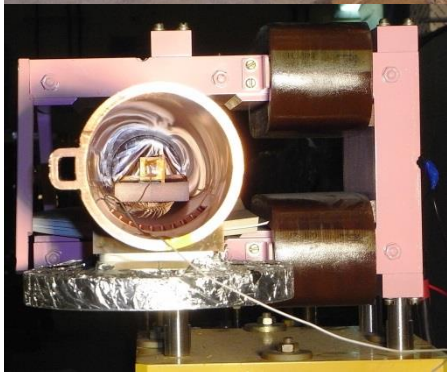
t: thickness (m),

ρ: resistivity ($\Omega \cdot$m)

A.W. Chao and M. Tigner, Editors,
Handbook of
Accelerator Physics and Engineering,
World Scientific, Singapore (1999), p. 268

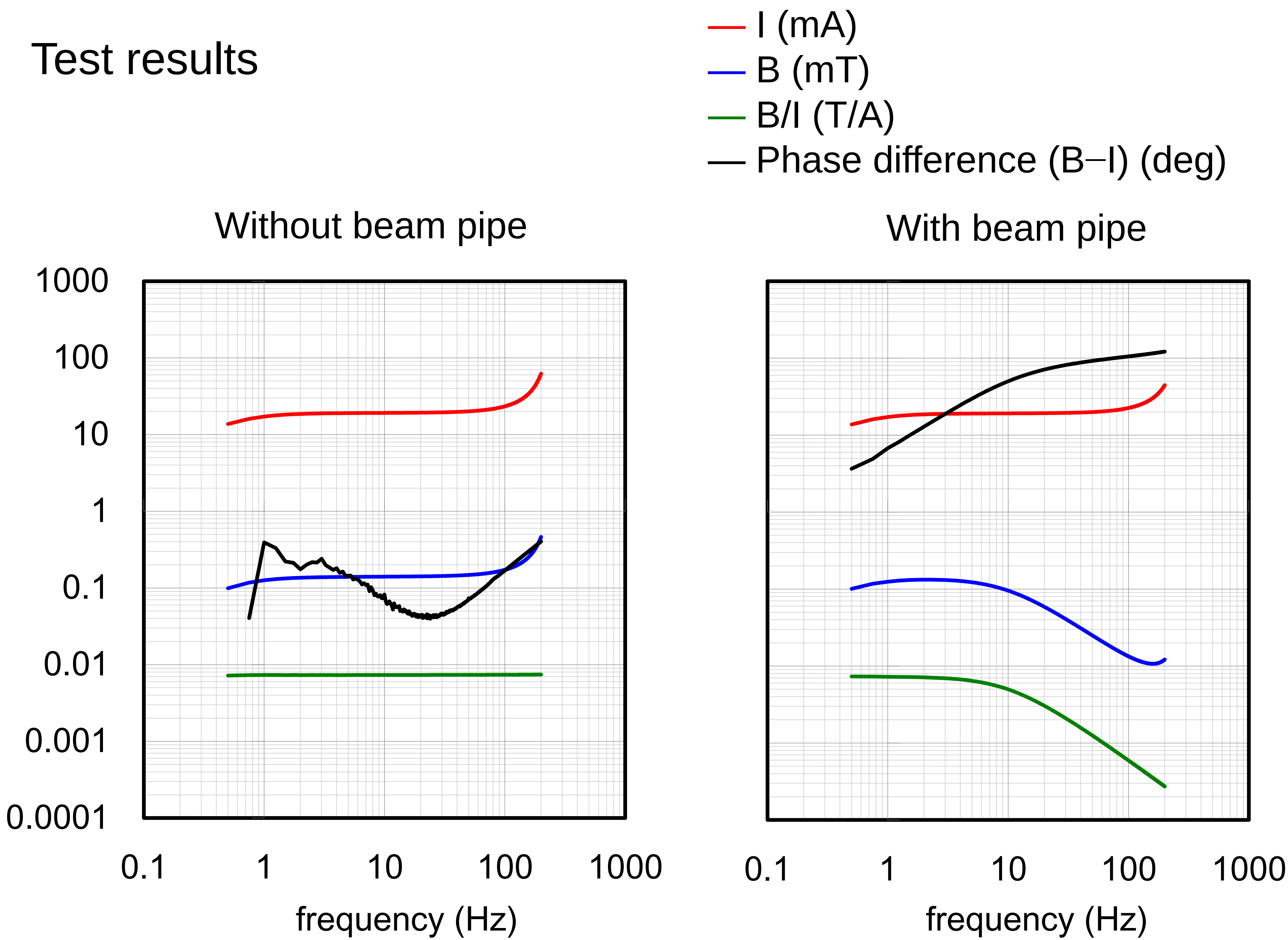
Test setup





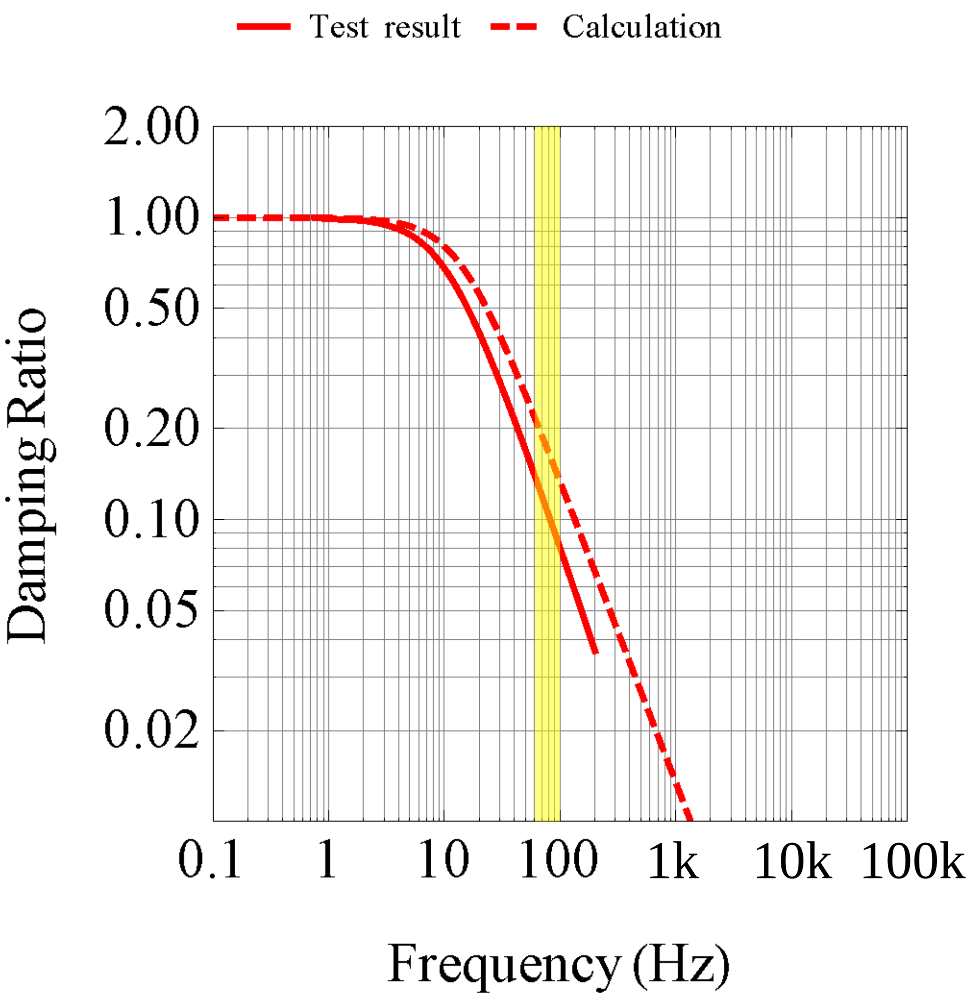
KEKB LER beam pipe made of copper:
53 mm radius, 6 mm thickness.

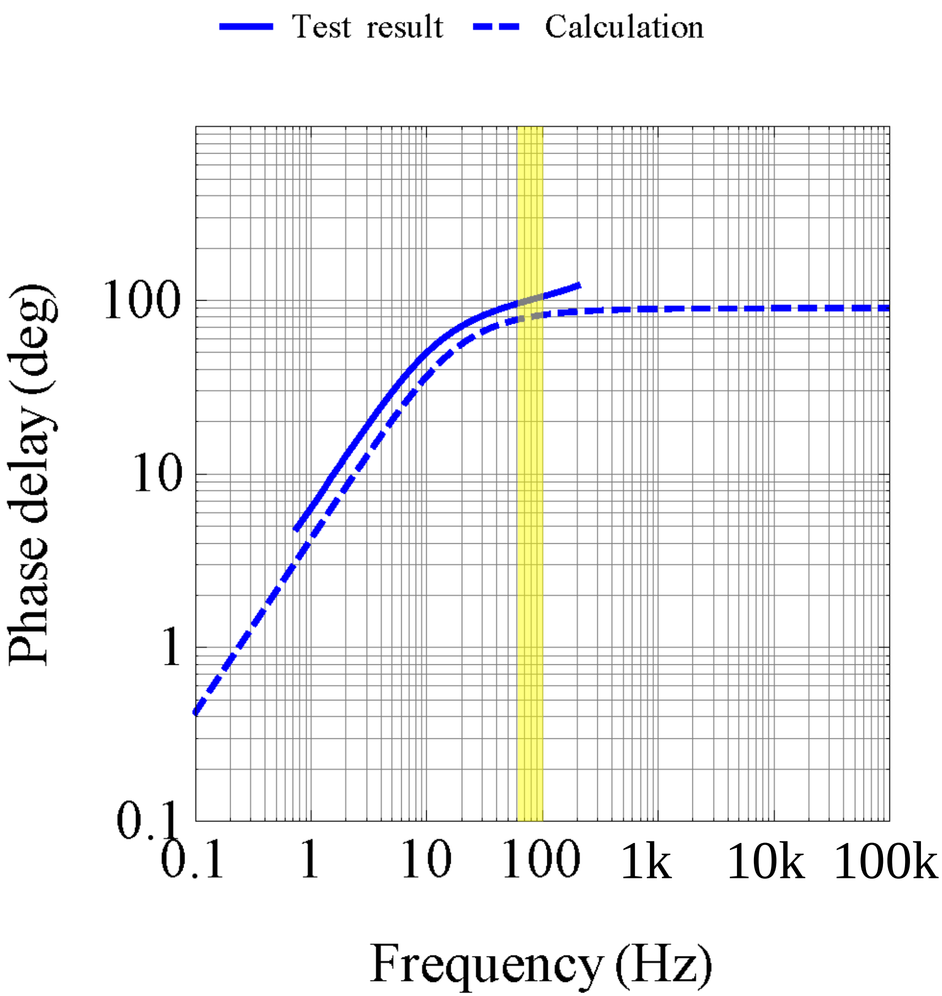
Test results



Test result summary

Material: Copper
Inner diameter: 94 mm
Thickness: 6 mm

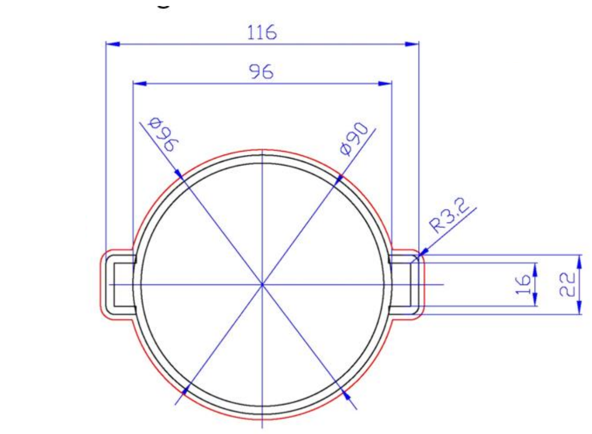


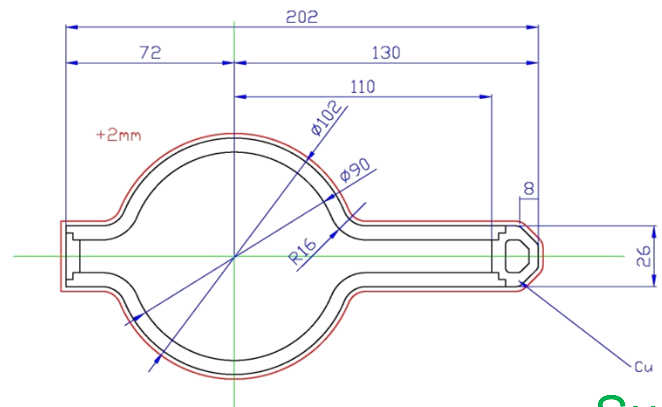


Good agreement with calculation.
Strongly damped at the target frequency range: Dithering (60~100 Hz)

Conceptual drawing of beam pipes

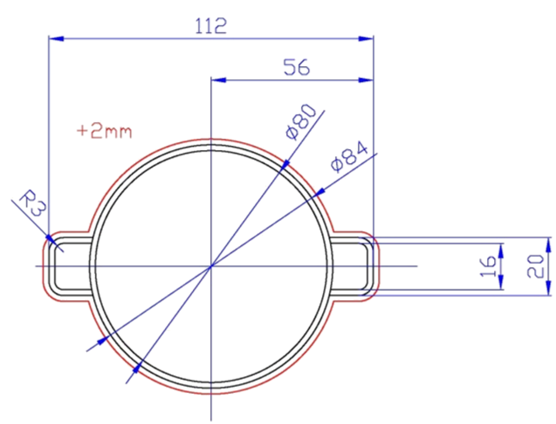
Material: SS316L
Inner diameter: 90 mm
Thickness: 3 mm for round type, 6 mm for antechamber
10 μm Cu coating inside.





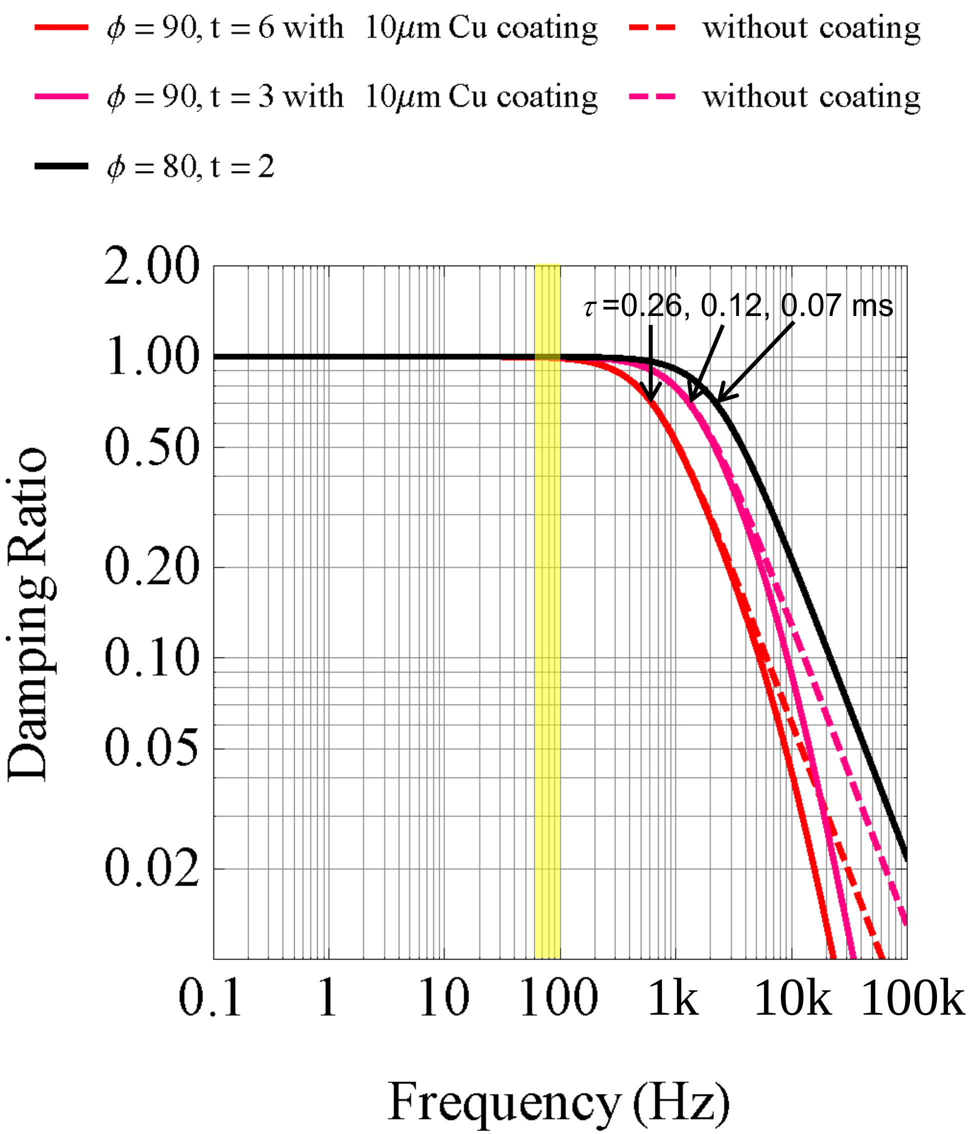
Suetsugu

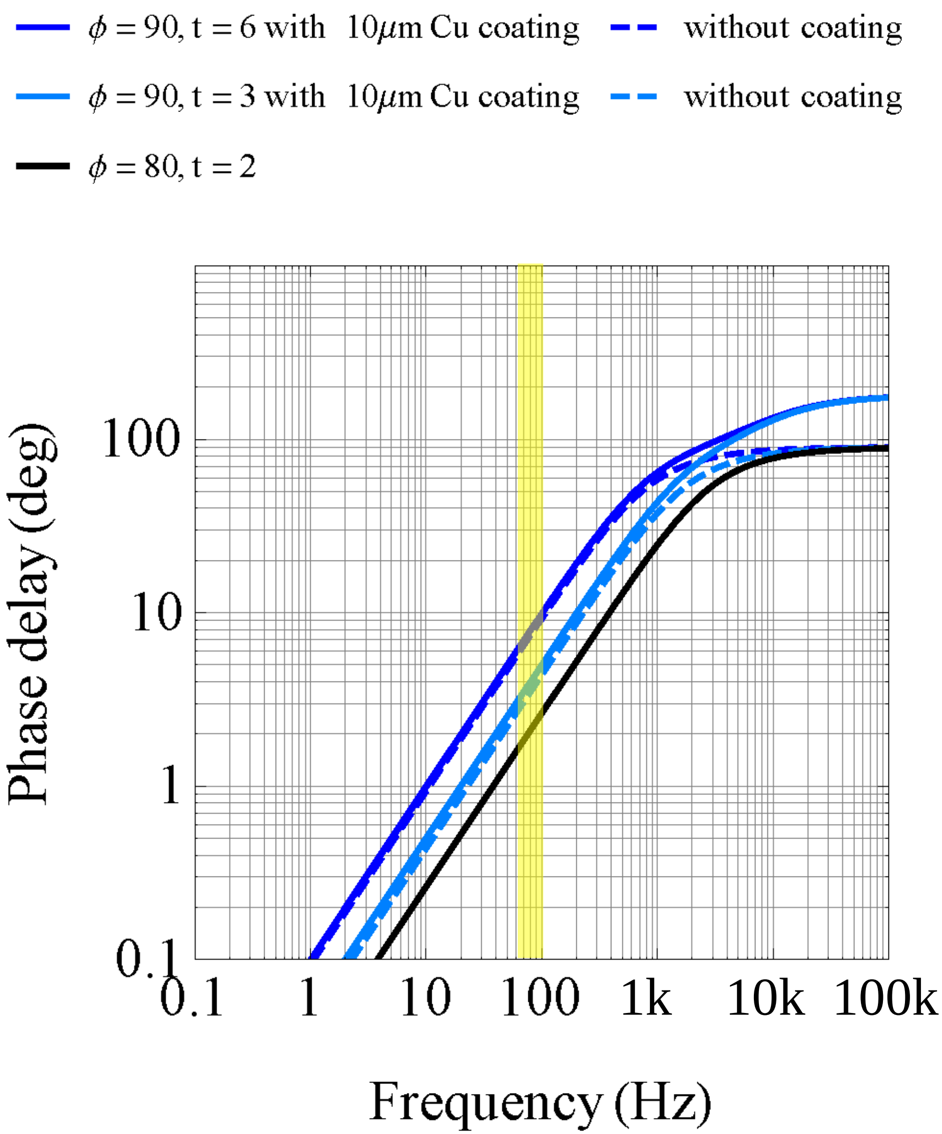
Material: SS316L
Inner diameter: 80 mm
Thickness: 2 mm



Kanazawa

Calculations for the round SS beam pipes





Resistive and thinner pipe suppresses the damping effect.
The Cu coating is effective above 1 kHz.