あいちSRにおけるパルス６極電磁石による蓄積ビームへの影響

PERTURBATION TO THE STORED BEAM BY PULSED SEXTUPOLE MAGNET IN AICHI-SR

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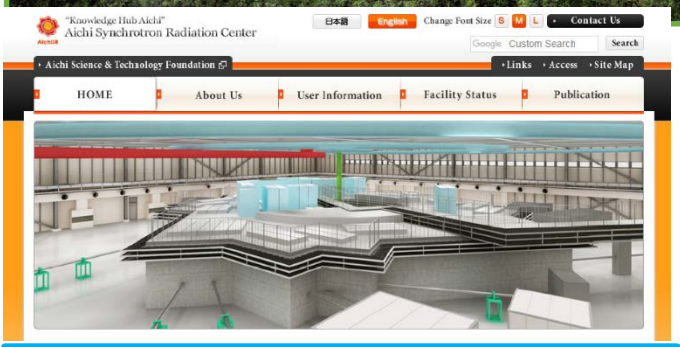
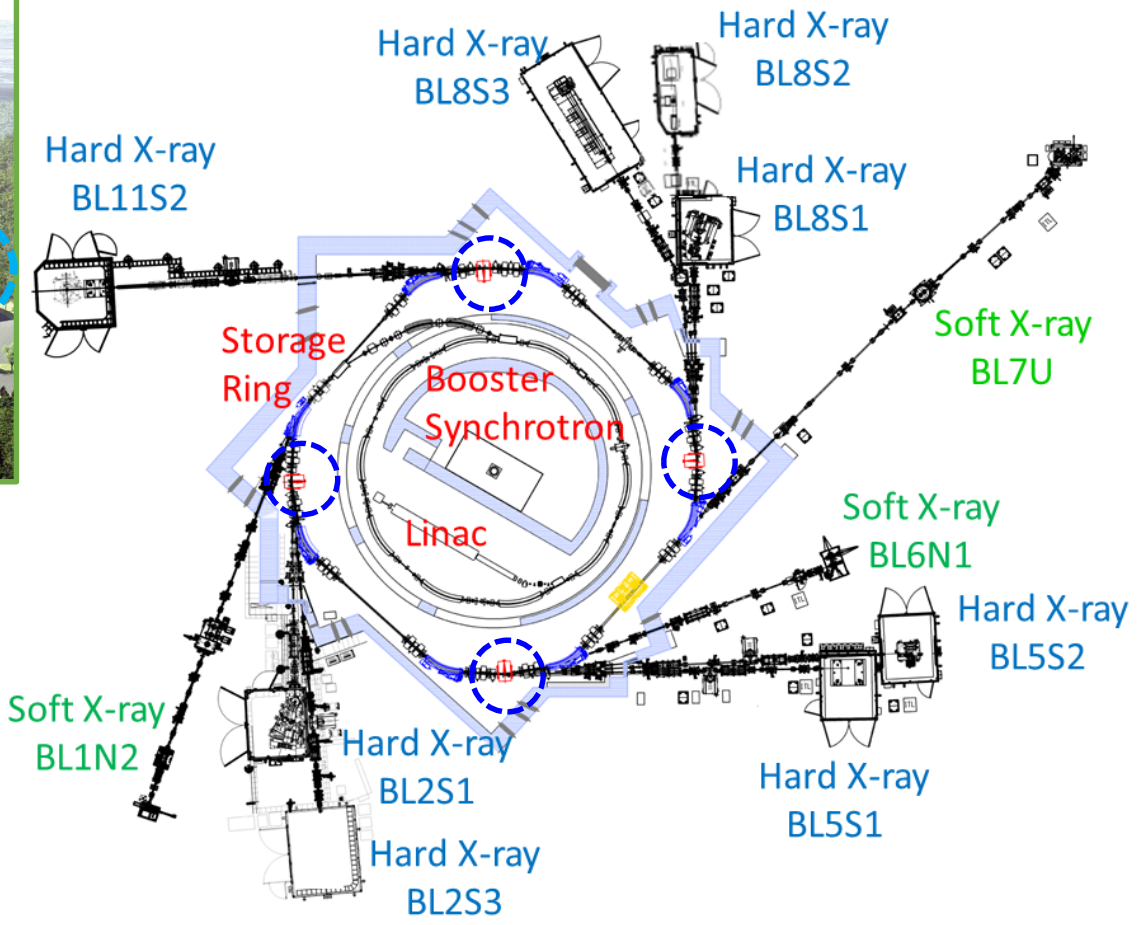
Introduction : Aichi-SR



Hard-X beamlines … 8
Soft-X beamlines … 3
in 1.2GeV Ring



4-Superbends have been operated stably.

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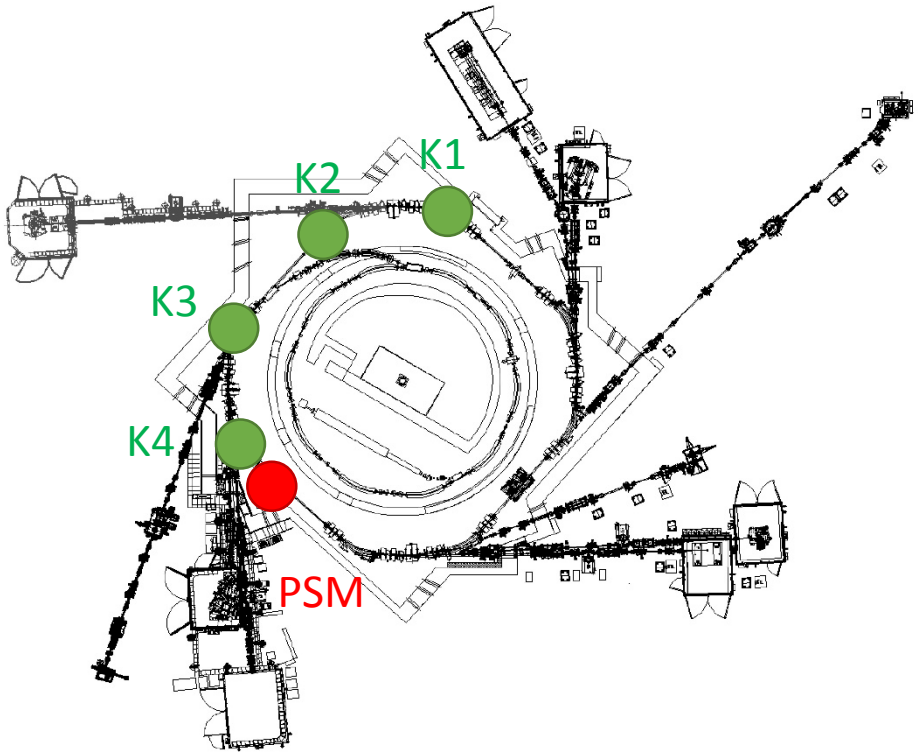
Accelerator Complex

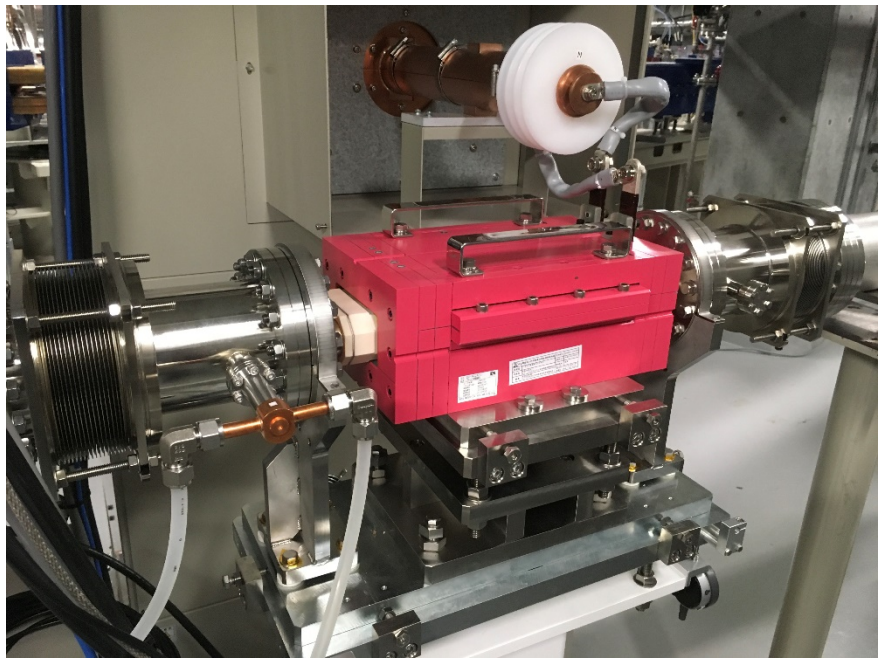
Storage Ring		
Beam energy	1.2	GeV
Circumference	72	m
Beam current (Top-up)	300	mA
Natural emittance	53	nm-rad
RF frequency	499.69	MHz
Harmonic number	120	
Revolution time	240	ns
Energy spread	8.4×10^{-4}	
Momentum compaction	0.018	
(ν_x, ν_y, ν_s)	(4.73, 3.18, 0.01)	

Booster Synchrotron		
Beam energy	50 MeV →1.2 GeV	
Circumference	48	m
Beam current	~ 1	mA
Repetiton rate	1	Hz

Linac		
Beam energy	50	MeV
Charge	~1	nC/pulse
Pulse length	~ 1	ns
RF frequency	2856	MHz
Repetition rate	1	Hz

Pulse Sextupole Magnet (PSM) system in Aichi-SR





PSM installed in Aichi-SR, 2015.

Usual injection … 4 kicker bump method
4 beamlines are affected by the bump.

The beam injection rate by PSM is comparable to that by 4-kicker bump method.

BUT, **the stored beam** is perturbed by PSM excitation.

PSM yoke and ceramic duct

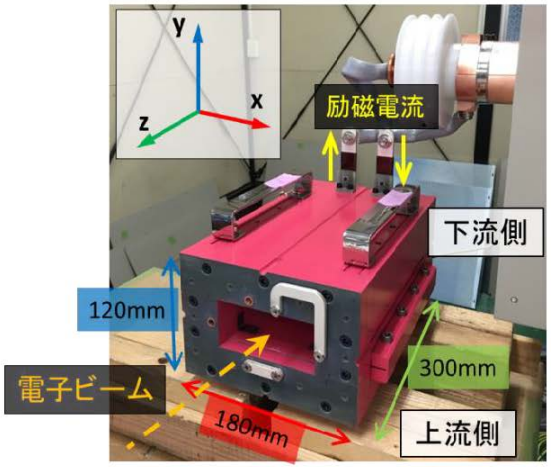


図 3.1 製作した PMM

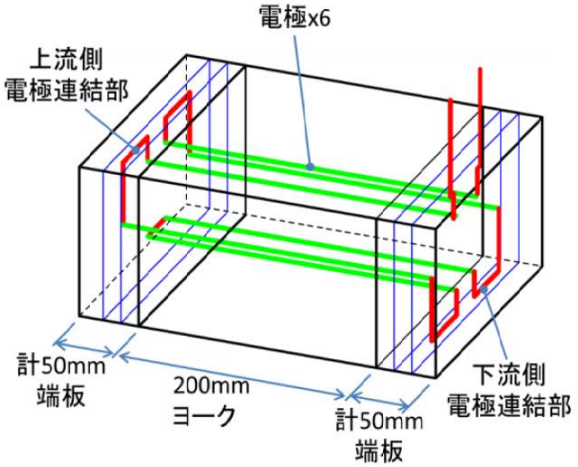


図 3.2 PMM の構成要素

0.2mm thickness
Laminated silicon steel sheet
Yoke length … 200mm

1μm thickness (nominal)
Ti coating inside ceramic duct

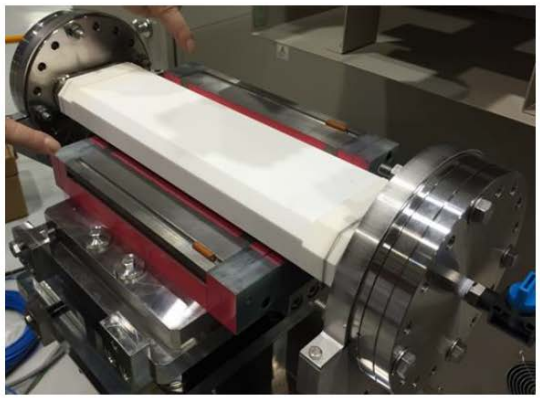
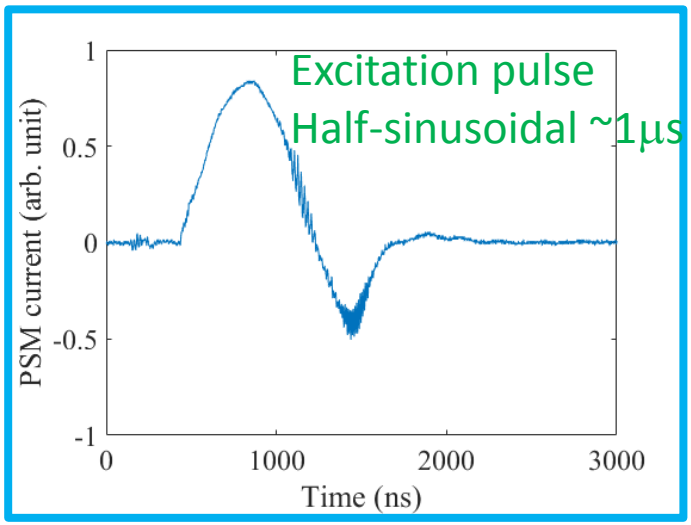


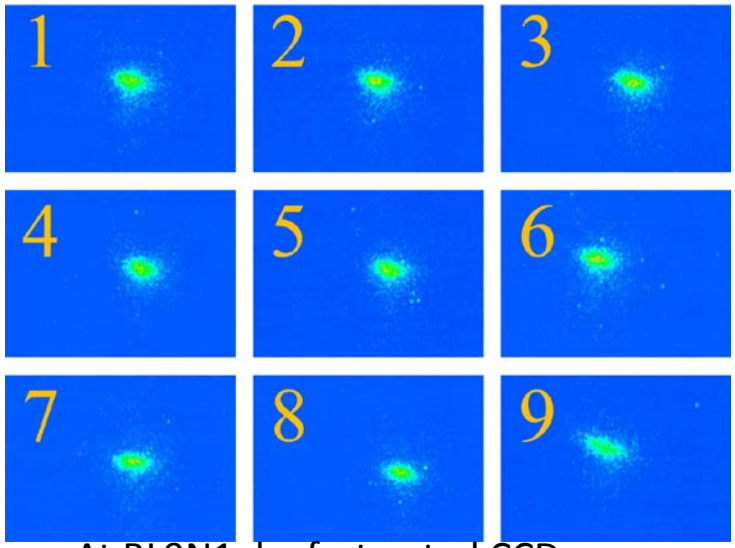
図 3.6 セラミックダクトの全体像

図 3.7 ダクト内壁の Ti コーティング



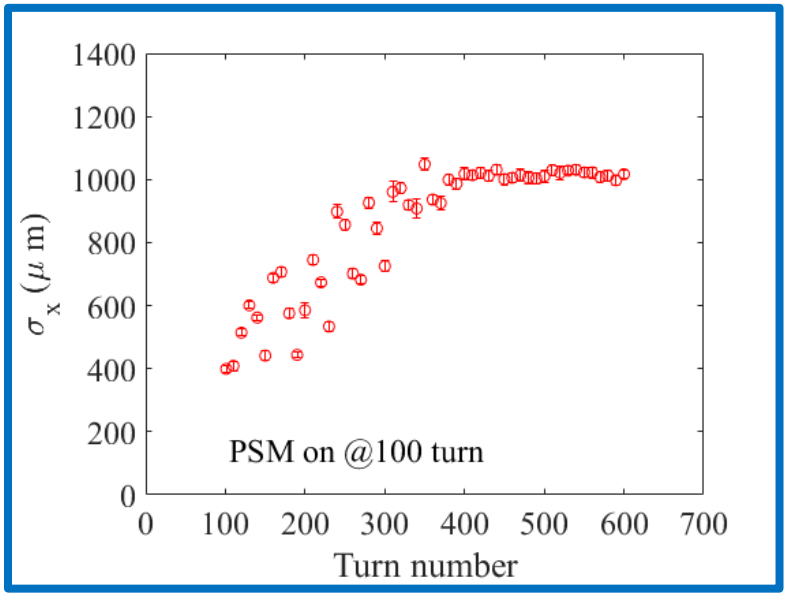
K. Ito, Master thesis (Nagoya University, 2016)

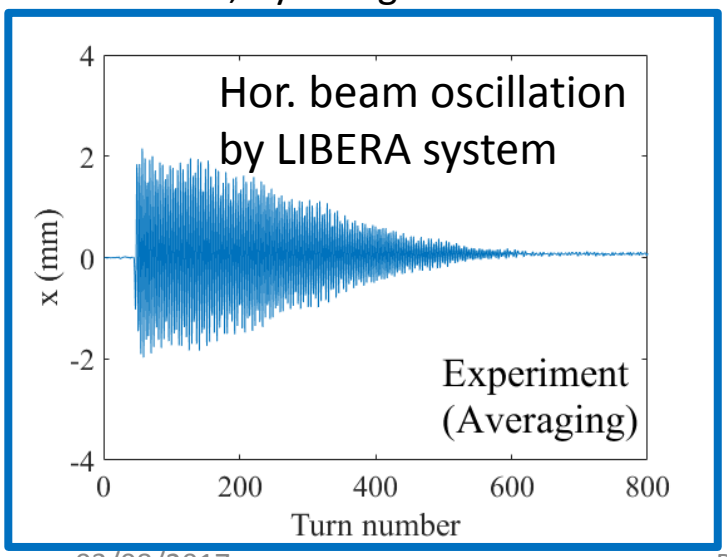
Beam diagnostic experiments



At BL9N1, by fast-gated CCD camera

Turn-by-turn measurement





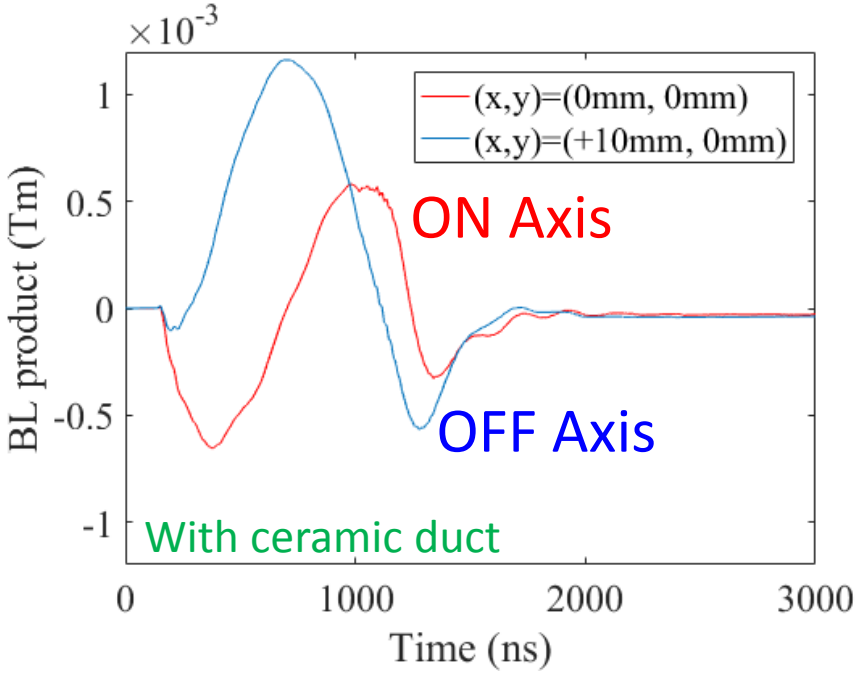
The horizontal beam size increases quickly just after PSM is ON.

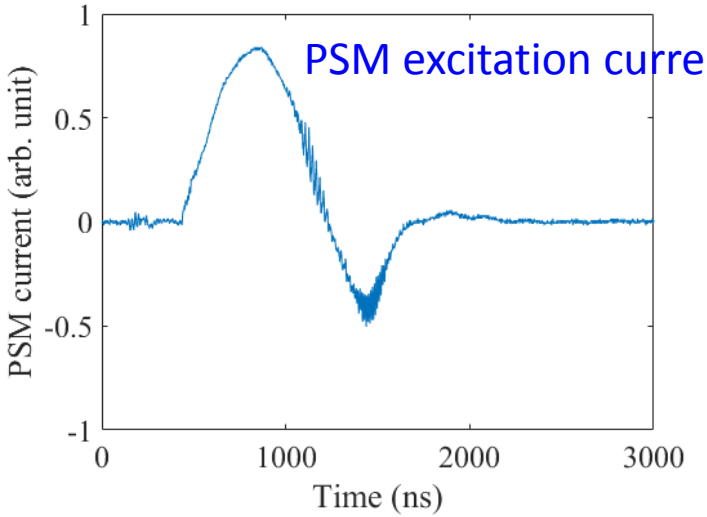
After ~300turns PSM on, the beam size tends to be saturated.

The oscillation of the beam center ceases after ~600turn PSM on.

Mag. field measurement (1)

- Long coil measurement … BL product





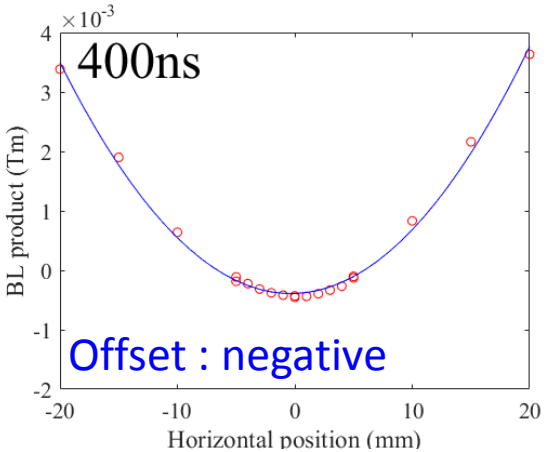
The BL product waveform at OFF-AXIS reflects the excitation current pulse shape of PSM.

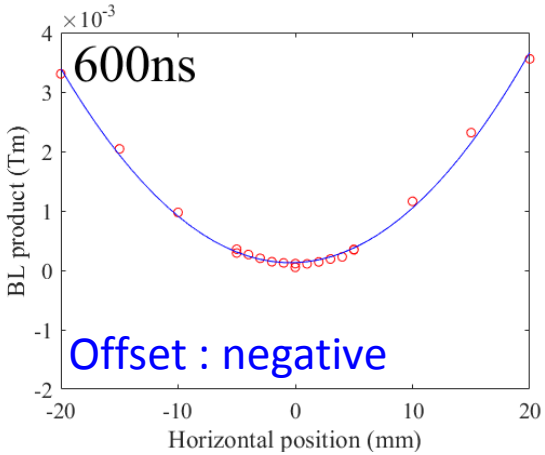
BUT, even at ON-AXIS we have the BL product waveform which has significant value.
The waveform at ON-AXIS resembles derivative of the excitation current pulse.

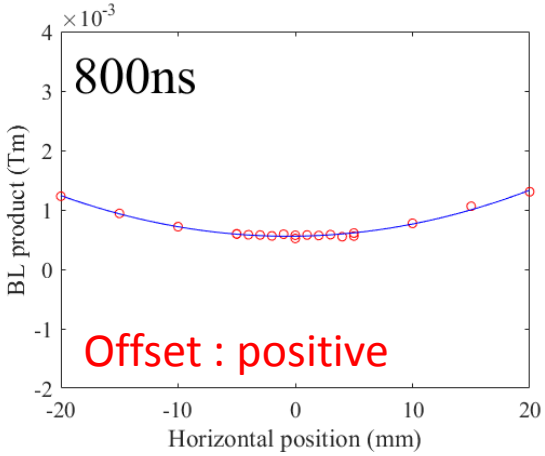
Mag. field measurement (2)

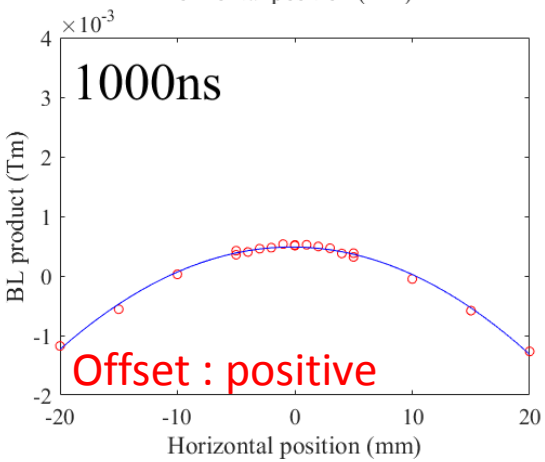
- Long coil measurement … BL product

With ceramic duct

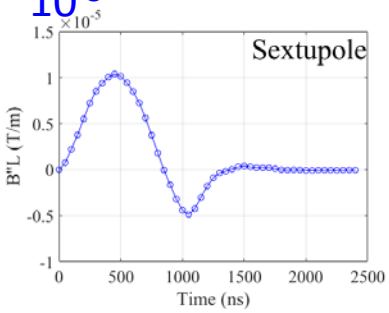




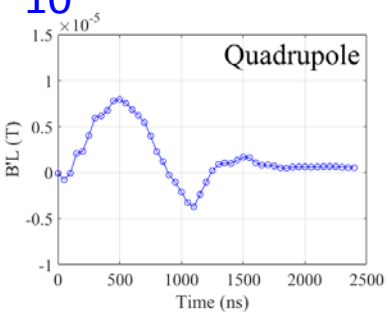




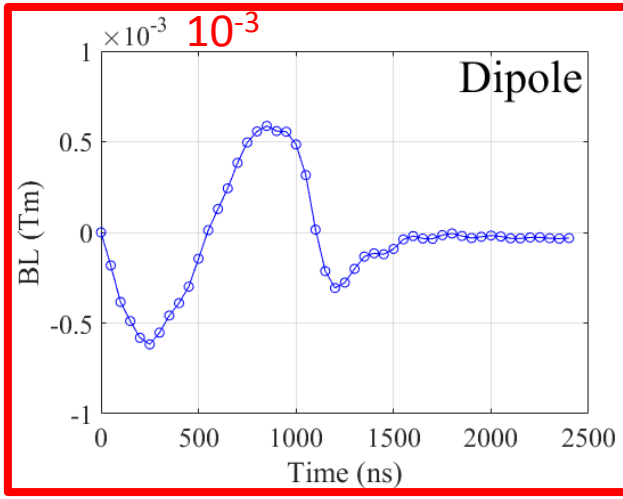
10^{-5}



10^{-5}



10^{-3}



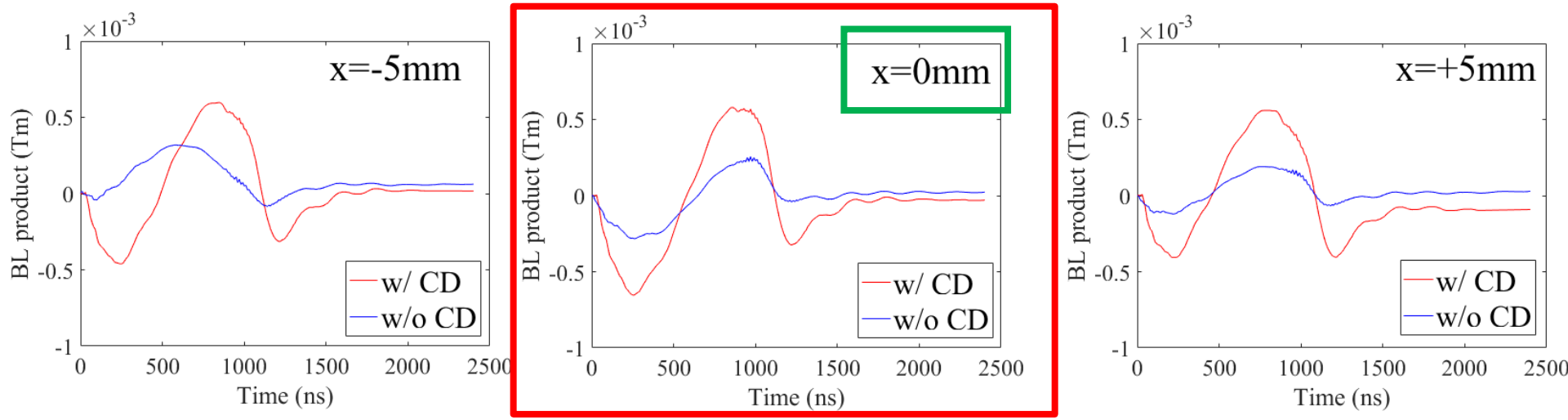
Dipole component is the main source of the perturbation.

Magnetic field distributions on horizontal axis

Mag. field measurement (3)

- Long coil measurement … BL product

With/without ceramic duct



The BL product waveforms with ceramic duct resemble the derivative of the PSM excitation pulse waveform.

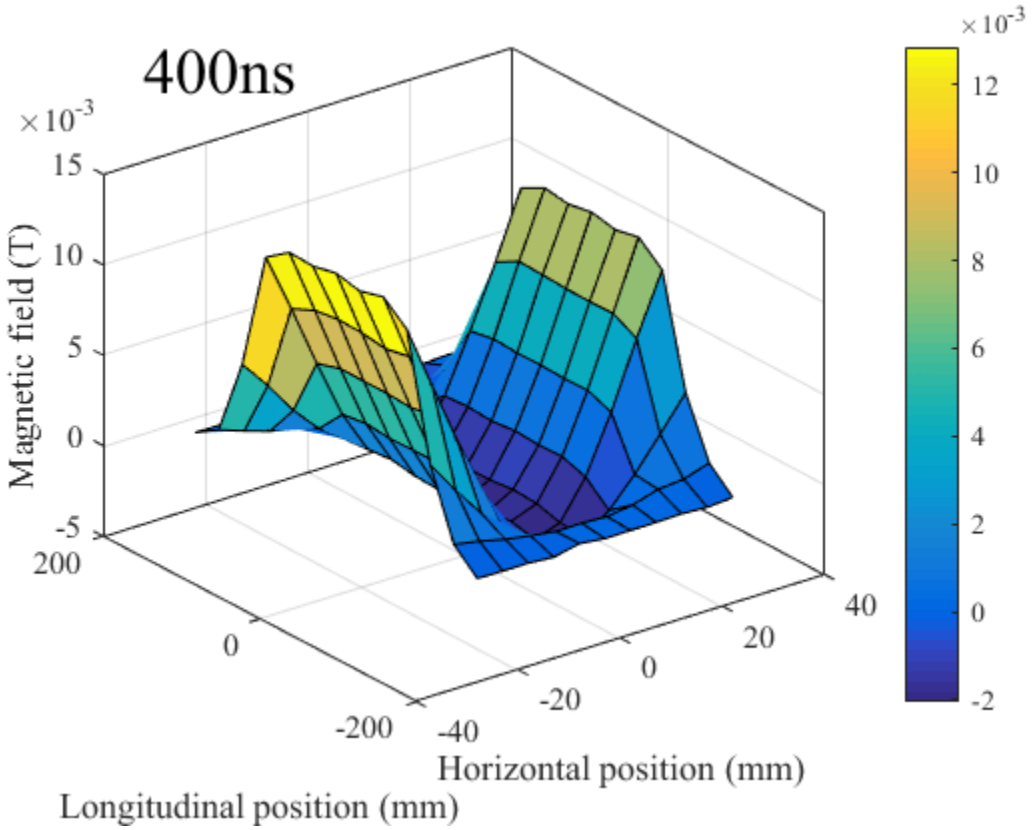
The BL product waveforms without ceramic duct at OFF-AXIS reflect the PSM pulse shape.

EVEN without ceramic duct at ON-AXIS, we have BL product whose waveform resembles the derivative of the PSM pulse waveform.

Mag. field measurement (4)

- Short coil measurement … mag. field

With ceramic duct



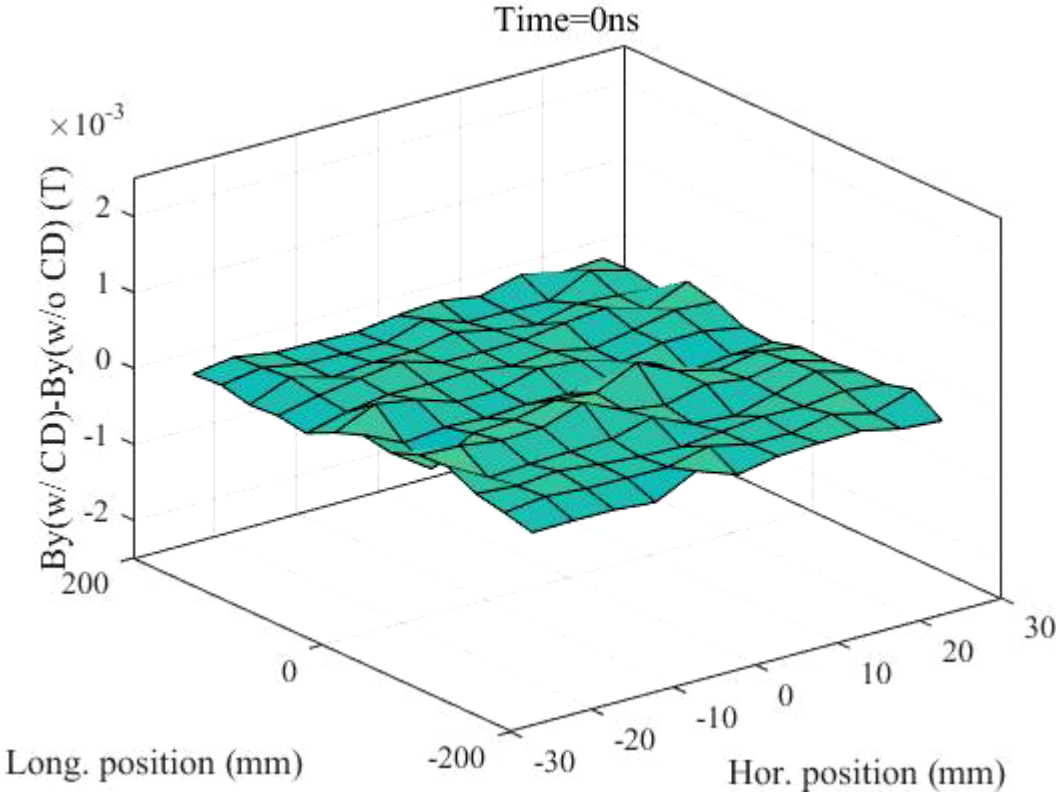
The results of short coil measurements indicate that :

1) the magnetic field distribution is parabolic along the longitudinal position (beam axis).
2) the residual magnetic field found in the long coil measurement is not caused by the field at the edge of PSM.

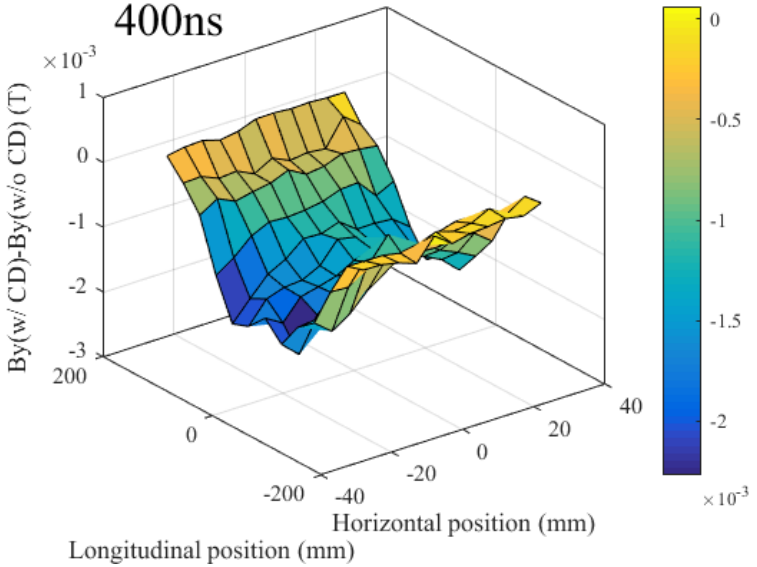
Mag. field measurement (5)

- Short coil measurement … mag. field

With/without ceramic duct



By(With C.D.) – By(Without C.D.)



The residual magnetic field by EDDY CURRENT by Ti-COATED CERAMIC DUCT is almost flat in horizontal direction.

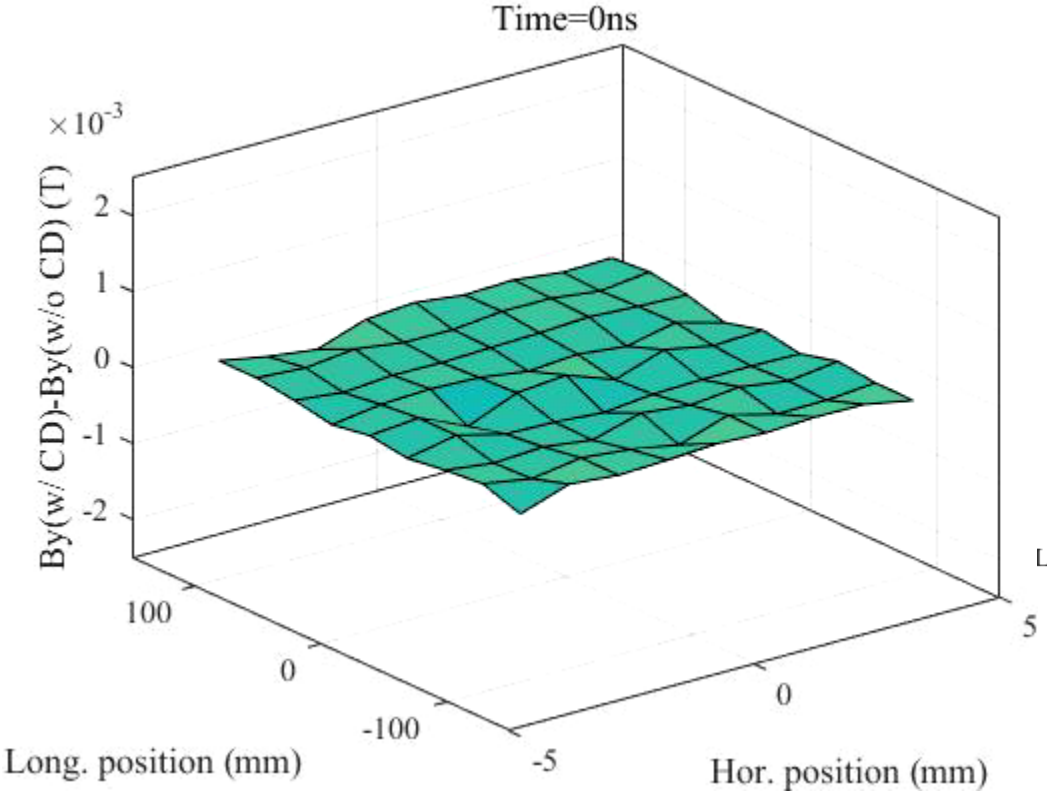
DIPOLE KICK

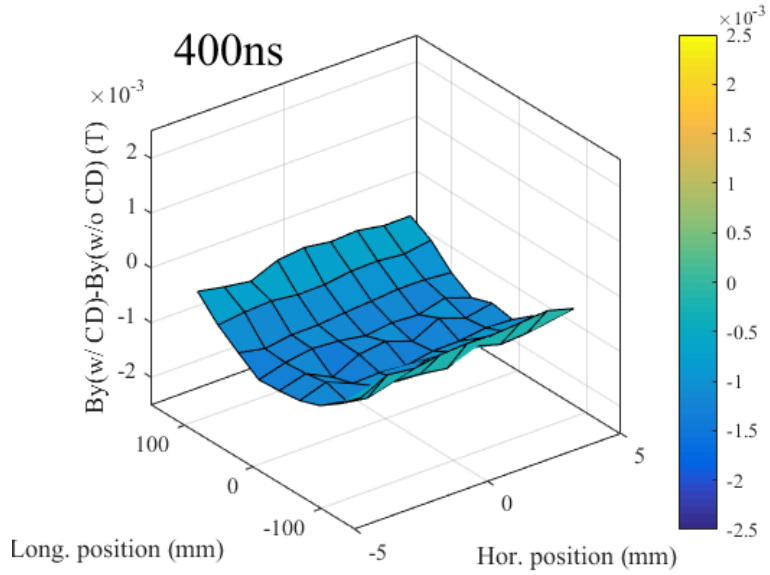
Mag. field measurement (6)

- Short coil measurement … mag. field

Around beam axis

With/without ceramic duct





By(With C.D.) – By(Without C.D.)

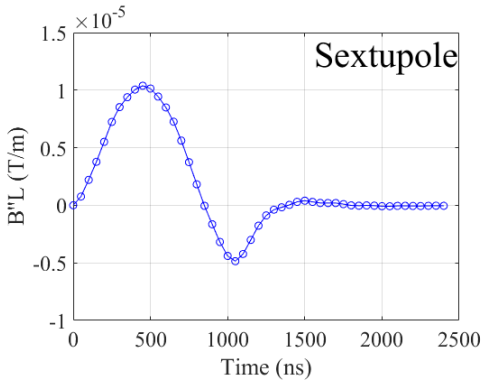
The residual magnetic field by EDDY CURRENT by Ti-COATED CERAMIC DUCT is almost flat in horizontal direction.

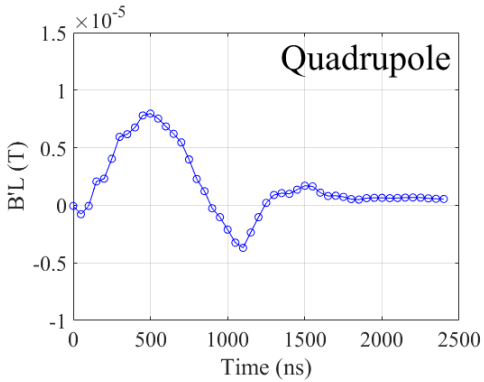
DIPOLE KICK

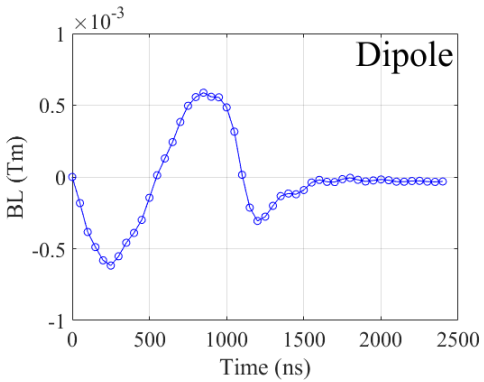
Simulation (1)

- Perturbation to the stored beam …

  from mag. measurement data, multi-turn kick (Trev=240ns)



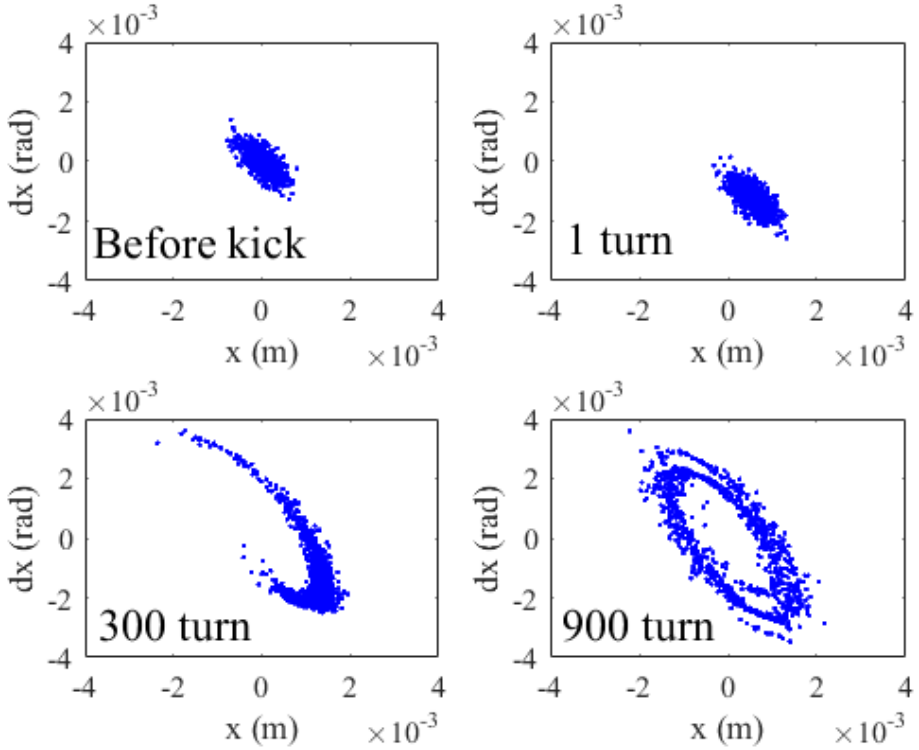




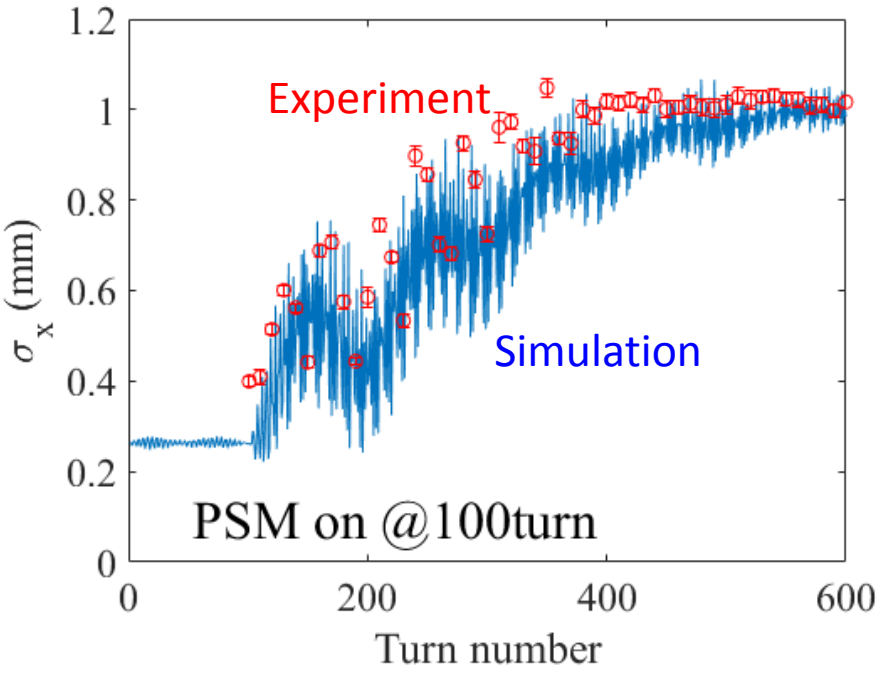
- 2-families of SFs, SDs
- Synchrotron oscillation is considered
- Number of calculated turns … 1000 :

  radiation damping time = 28000turn (negligible)
- Number of particles = 1000

Simulation (2)

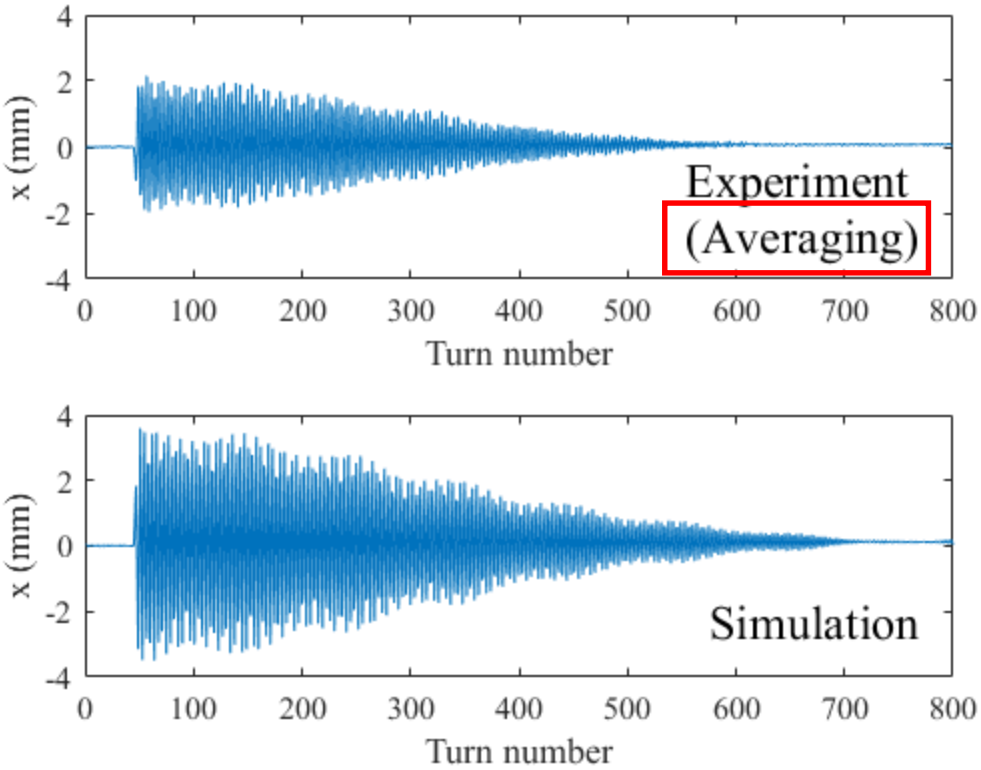


After the kick by PSM, the stored beam starts to spread out rapidly over the phase space.



After ~300 turns, the horizontal beam size tends to be saturated because of the spreading-out over the phase space.

Simulation (3)



Horizontal beam oscillation measured by LIBERA system (above) and simulation result (bottom).

The measured oscillation amplitude is smaller than that from simulation.

One of the reason of the disagreement could be stability of trigger signal for PSM power source, LIBERA system….

Because we observed the oscillation by averaging several shots, the measured data would be smaller than the real value.

ADDITIONAL EXPERIMENTS ARE NECESSARY

Summary

- In Aichi-SR, the PSM system has been installed since 2015, and the beam injection has been successfully done with sufficient injection rate.
- By beam diagnostic experiments, however, the perturbation to the stored beam by exciting PSM has made clear.
- To investigate this, we have analyzed the magnetic field measurement data observed by long and short coil. From the analysis, we have found that most of the source of the perturbation comes from DIPOLE magnetic component at on-axis position.
- We also have found there is significant mag. field difference between with and without ceramic duct. This strongly indicates that the residual mag. field comes from eddy current induced on Ti coating inside the ceramic duct.
- The simulation based on the measured magnetic field roughly agrees with the experimental results. More additional experiments are needed.

To suppress the oscillation (Next step, to be considered)

- Ti coating
  - Making some pattern to suppress the eddy current on the coating
  - Coating thickness

- Counter kick
  - To apply counter dipole-kick at proper position where the betatron phase advance condition is satisfied.

  (Now under consideration)