March. 1, 2005

Core-university Seminar

A Project of Sub-picosecond Light Pulse Generation from the SPring-8 Storage Ring

T. Nakazato

SPring-8

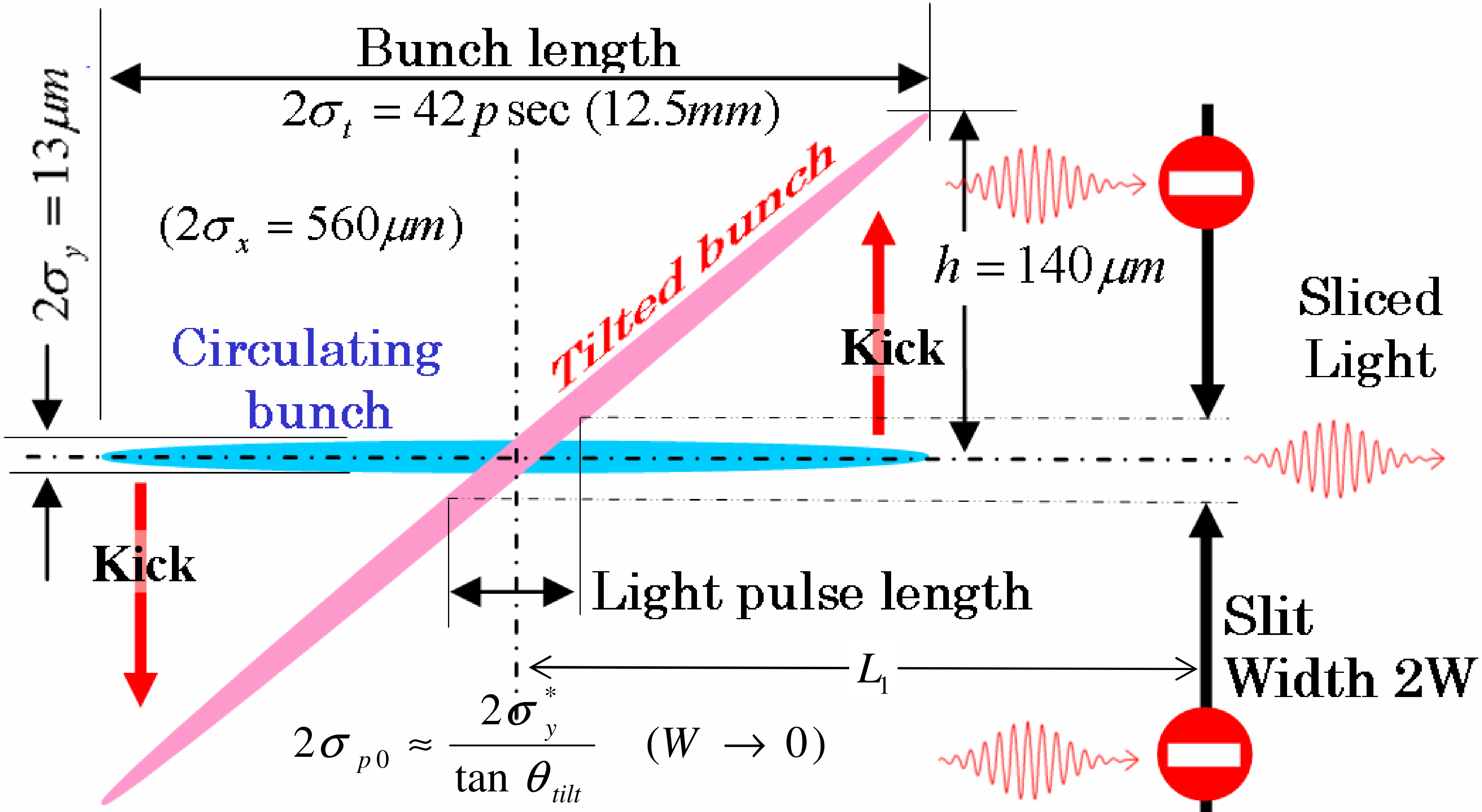
Contents

- Principle and concept design of a short pulse generator.
- Pulse width and extraction efficiency.
- Beam loss by the short pulse generator.
- Phase noise of RF system at SP8.
- R&D

  1)Phase stability & vibration measurement at KEK : basic data for system design.

  2)Fast 300kW phase shifter.

Generating a short light pulse from a bunch at Spring-8

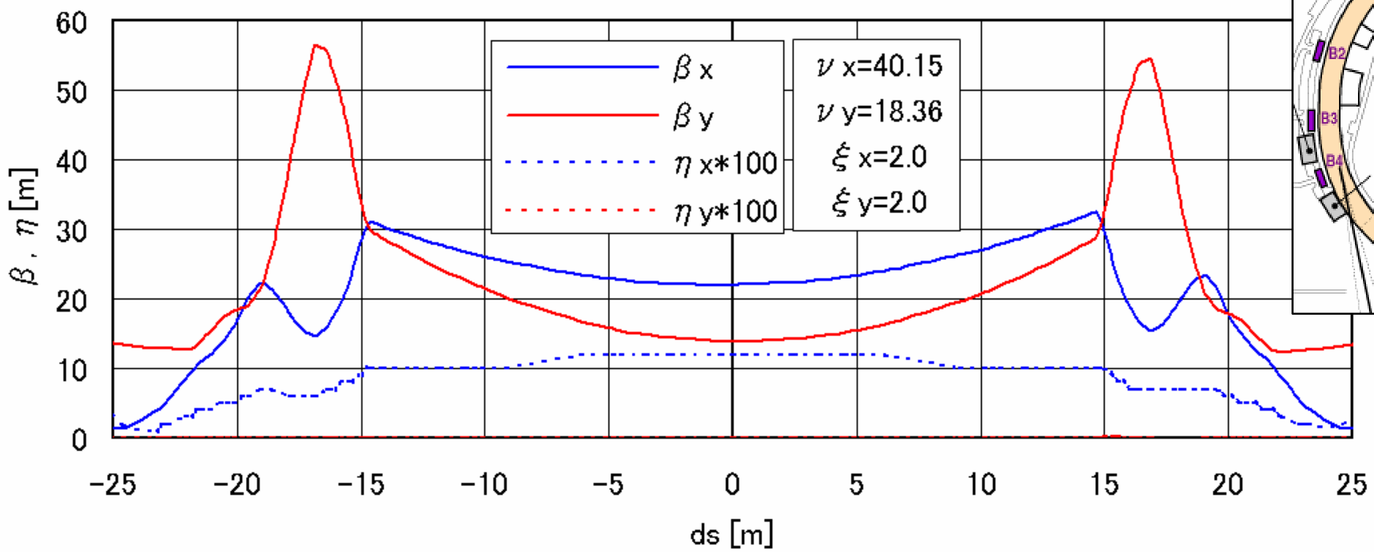


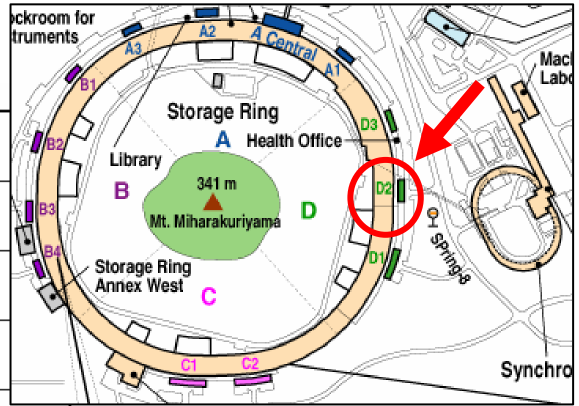
$$2\sigma_{p0} \approx \frac{2\sigma_y^*}{\tan\,\theta_{tilt}} \quad (W \to 0)$$

$= 1.9$psec (for no diffraction)

$$\tan\theta_{tilt} = \frac{h}{\sigma_t} = 6.7\,\mu\text{m/psec}$$

Concept Design of Short Pulse Generator at SP8

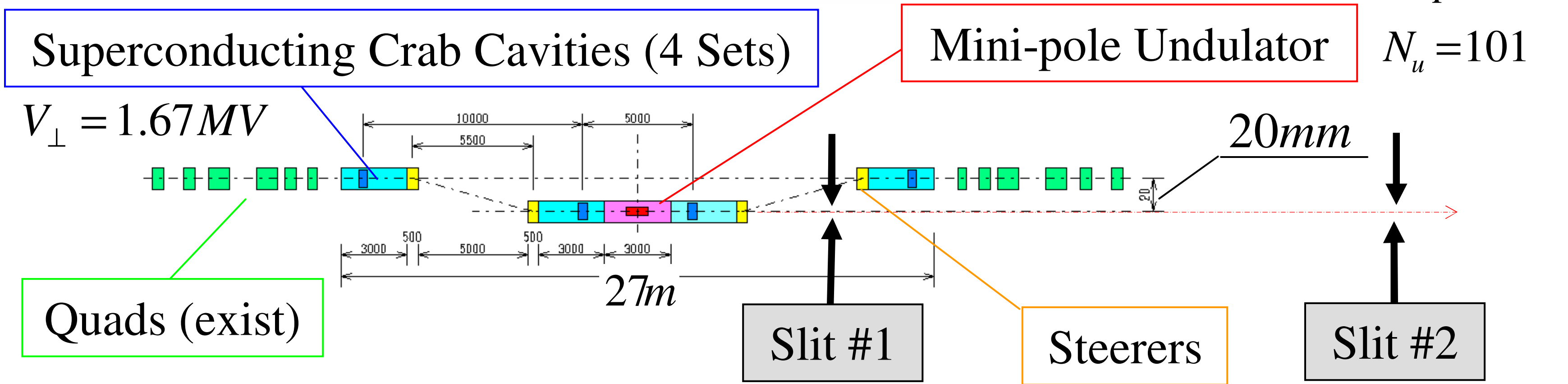


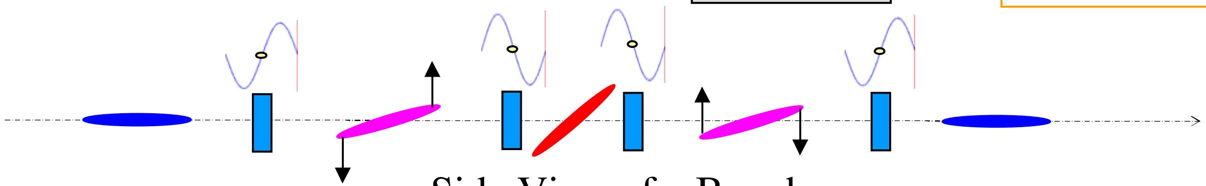


$\lambda_u = 10mm$

$Gap = 5mm$

$N_u = 101$





Side View of a Bunch

RF phase stability of
14 mdeg (0.24mrad) !

Storage Ring Parameters (1) (common for 4 & 8 GeV)

•Stored current (I_{beam})	1.5 mA (single bunch operation)
	100mA (multi bunch operation)
•Bunch population (N_b)	4.48×10^{10}
•Bunch charge (Q_b)	7.18×10^{-9} Coulomb
•Betatron tune (ν_x/ν_y)	40.15/18.35
•Coupling constant(κ)	0.1%
•RF frequency (f_{rf})	508.58 MHz
•RF Voltage (V_{rf})	16 MV
•Harmonic number (h)	2436
•Revolution Frequency (f_{rev})	208.8 kHz
•Momentum compaction factor (α)	1.46×10^{-4}
•Bending radius (ρ)	39.2718 m
•Longitudinal impedance ($Z_{//}/n$)	0.200 Ω

Storage Ring Parameters (2)

Electron beam energy	E	↓Scale	4.0	8.0	GeV
Lorentz factor	γ	$\propto E$	7.83	15.66	$\times 10^3$
Emittance	ε_x	$\propto E^2$	0.75	3.0	nmrad
	ε_y	$\propto E^2$	0.75	3.0	pmrad
Beam size *1	σ_x	$\propto E$	140	280	μm *2
	σ_y	$\propto E$	3.3	6.5	μm *3
Beam divergence *1	$\sigma_{x'}$	$\propto E$	5.9	12	μrad
	$\sigma_{y'}$	$\propto E$	0.23	0.46	μrad
Bunch length *4	σ_t	*5	17	21	psec (1σ)
			41	50	psec (FWHM)
Momentum spread	σ_p / p	$\propto E$	0.055	0.11	%
Peak current *4	I_{peak}	*5	167	137	A

*1:at the center of long straight sections.

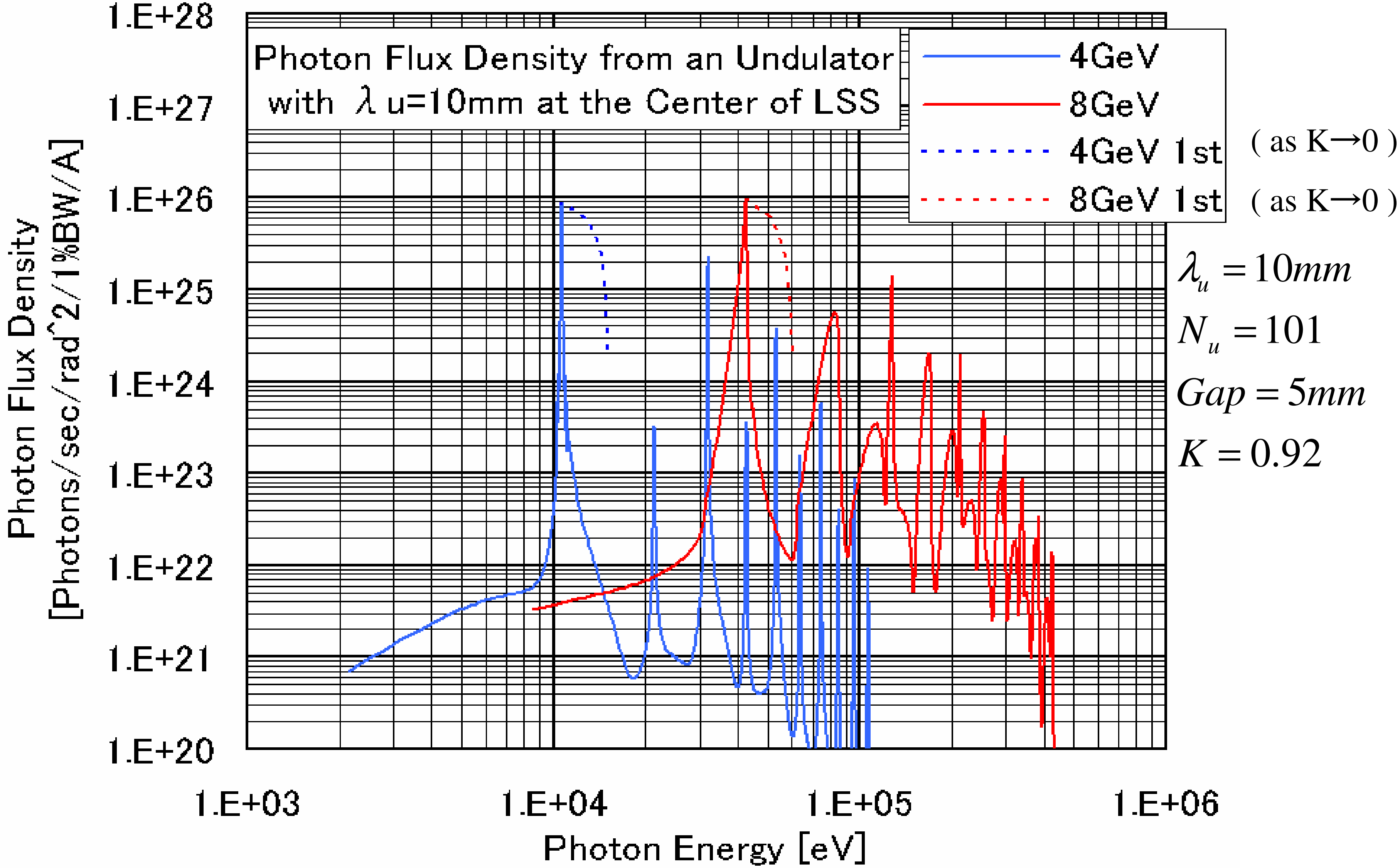
*2: $\eta_x \sigma_p / p$ is included.

*3: $\eta_y = \mathbf{0}$ is assumed.

*4:single bunch operation at I_{av}=1.5mA.

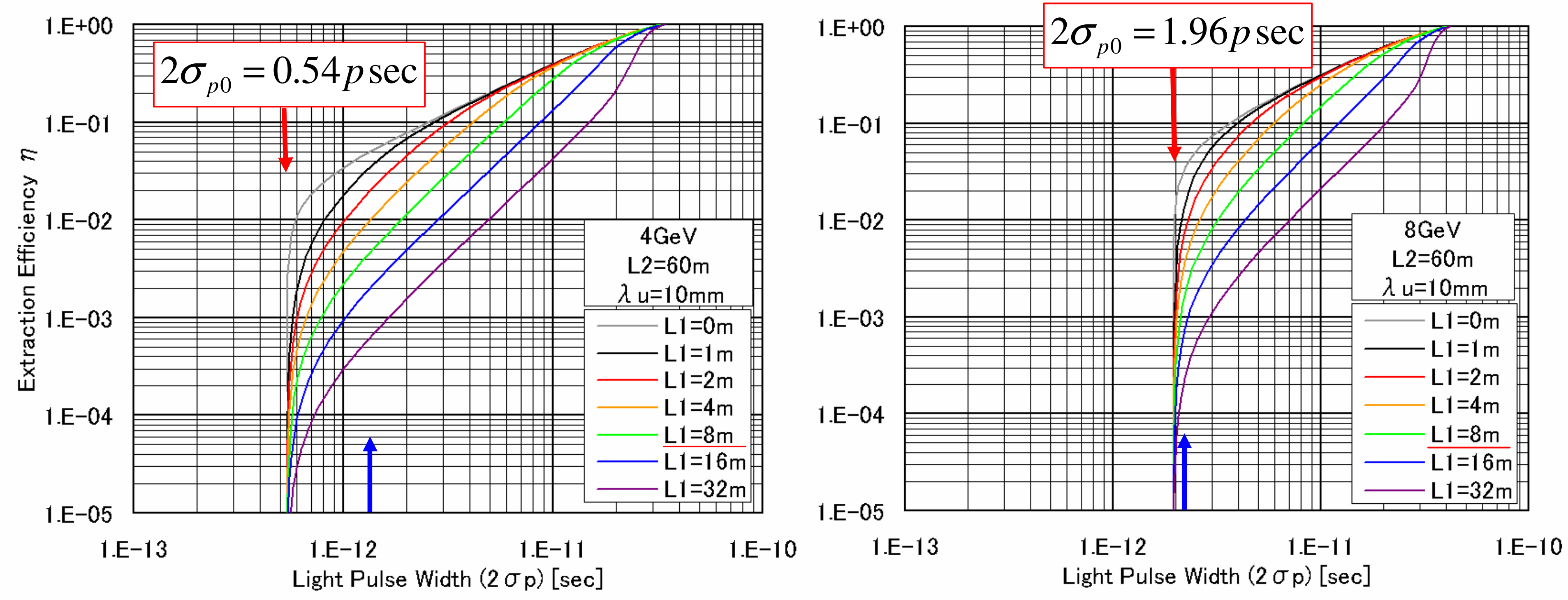
*5:not a simple function of E.

Light spectrum for 100% efficiency



■To get brilliance in Photons/sec/m^2/rad^2/1%BW, multiply 6.3×10^8 (4GeV) or 1.7×10^8 (8GeV) for the 1st order peak.

Light Pulse Width and Extraction Efficiency



$$\sigma_p^2 \approx \sigma_{p0}^2 + \frac{\pi}{3}\frac{h\Sigma'_y L_{12}}{\tan^2\theta_{tilt}}\eta \quad (\text{ for slit \#1 width} << \text{h})$$

$$\sigma_{p0} = \frac{\sigma_y^*}{\tan\theta_{tilt}}$$

L_1, L_2 : Distance from emission point to the slit #1 and #2.

$$\frac{1}{L_{12}} = \frac{1}{L_1} - \frac{1}{L_2}$$

Σ'_y : Width of radiation angular distribution.

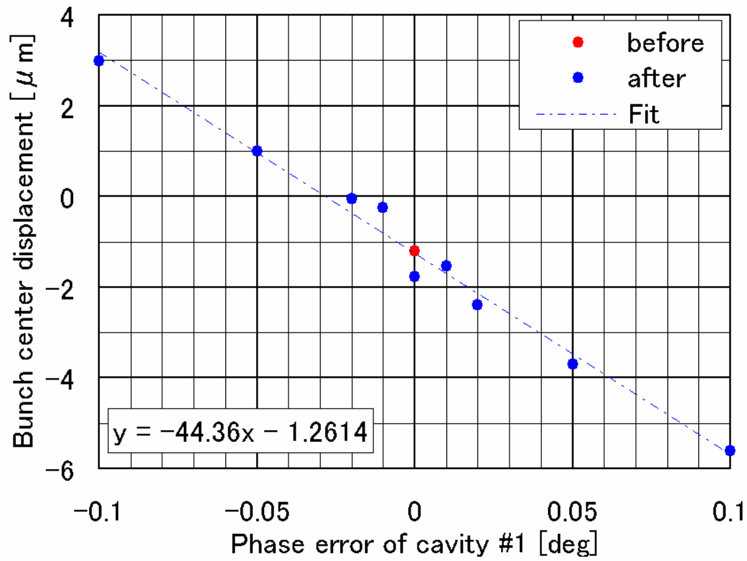
↑ shows $2\sigma_{p0}$ for standard undulators.

Asymmetric-cut crystal will improve the efficiency!

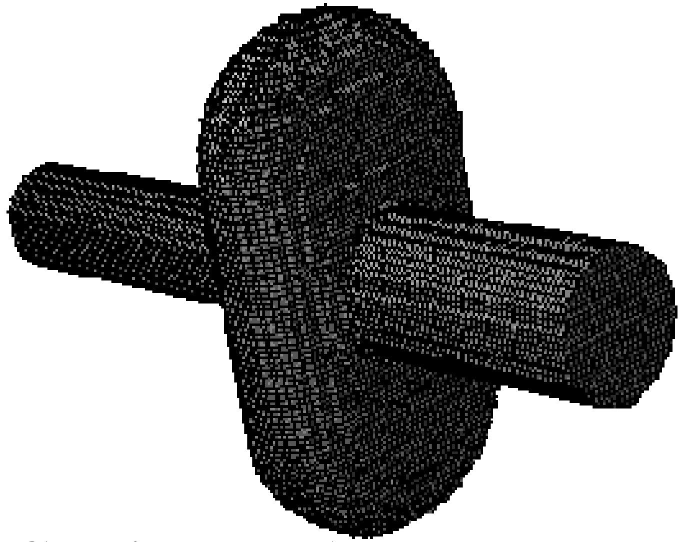
RF parameters (preliminary)

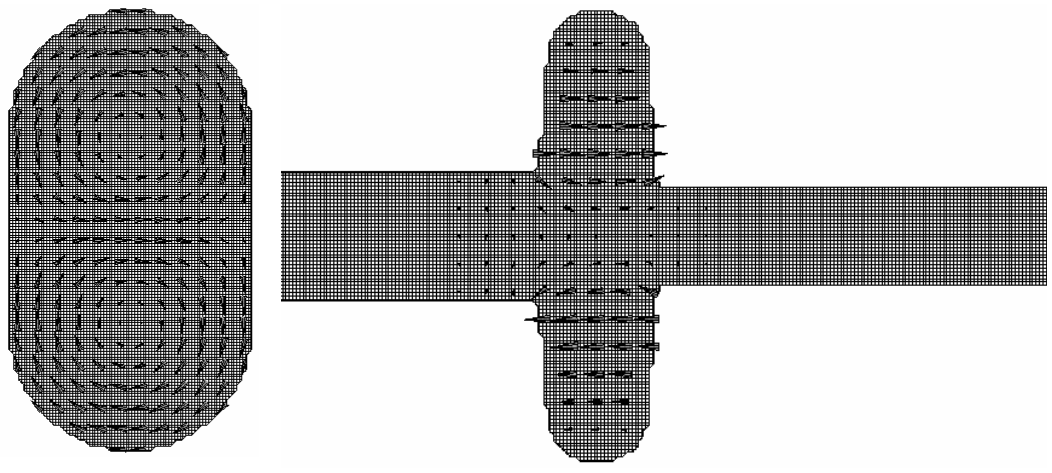
- Cavity Type Superconducting single cell
- Deflecting Mode TM110
- Number of Cavities 4
- Deflecting Frequency 508.58 MHz
- R/Q 64 Ω
- Loaded Q (Q_L) 5×10^4
- RF power 200 kW/Cavity
- Length of Drift Space 10 m
- Deflecting Voltage 1.67 MV
- Bunch Tilting 13.34 μm/psec at 4GeV

  6.67 μm/psec at 8GeV
- Phase stability 14 mdeg (0.24mrad) ←COD≦1 μm



Fields of the Crab Cavity.

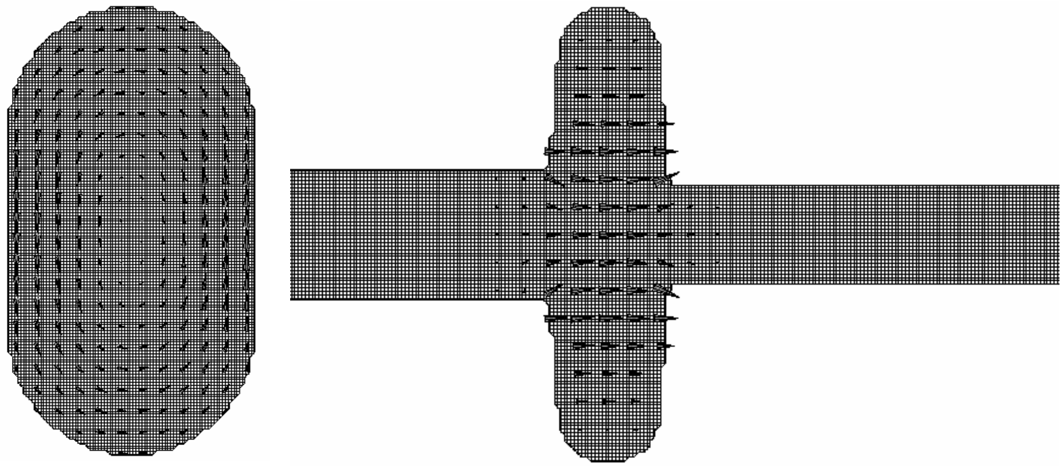




Deflecting mode

TM110 mode

f=508.58MHz

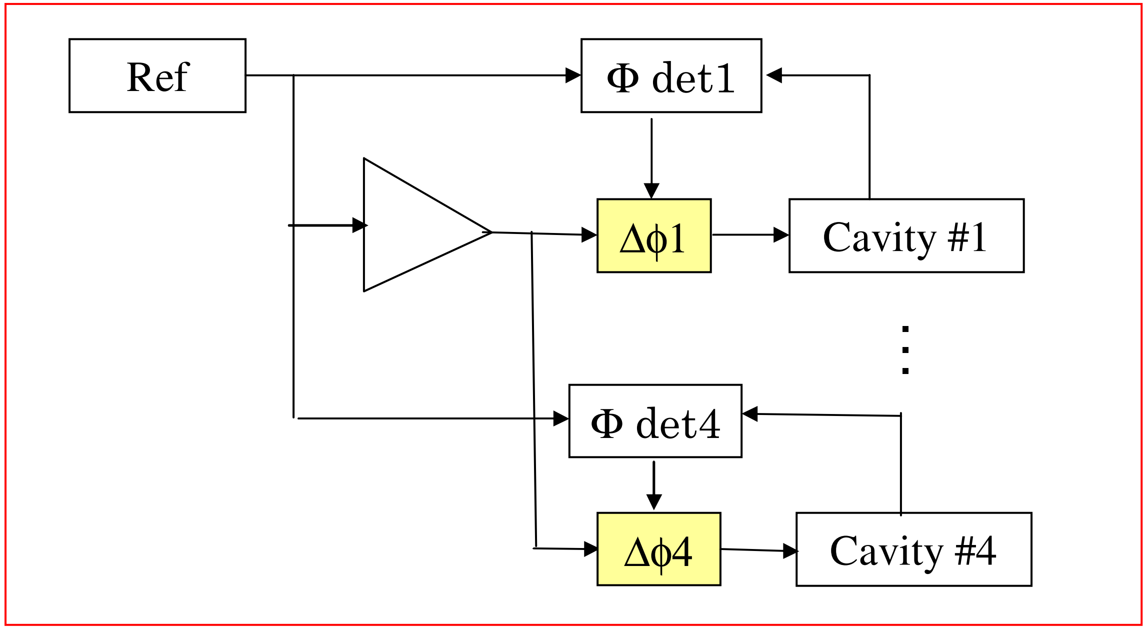


Lower order mode

TM010 mode

f=412.56MHz

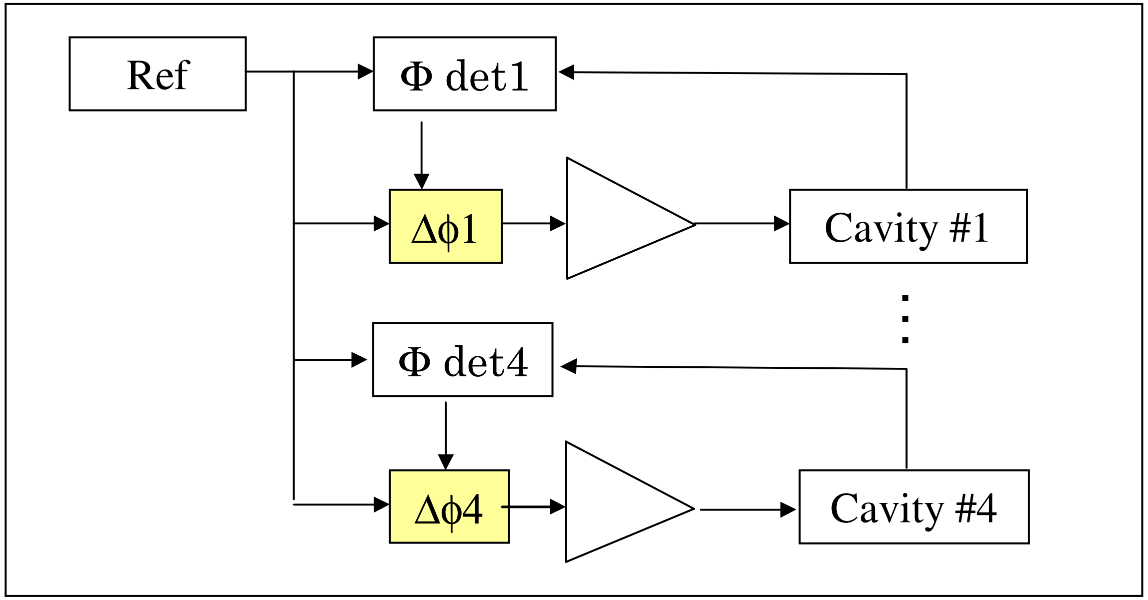
300kW fast phase shifter



Case A

High power phase shifter

Fed by same generator



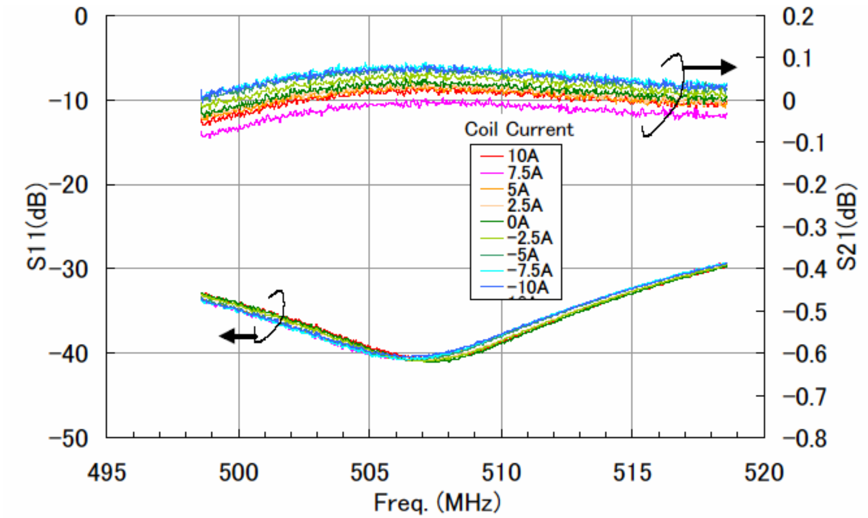
Case B

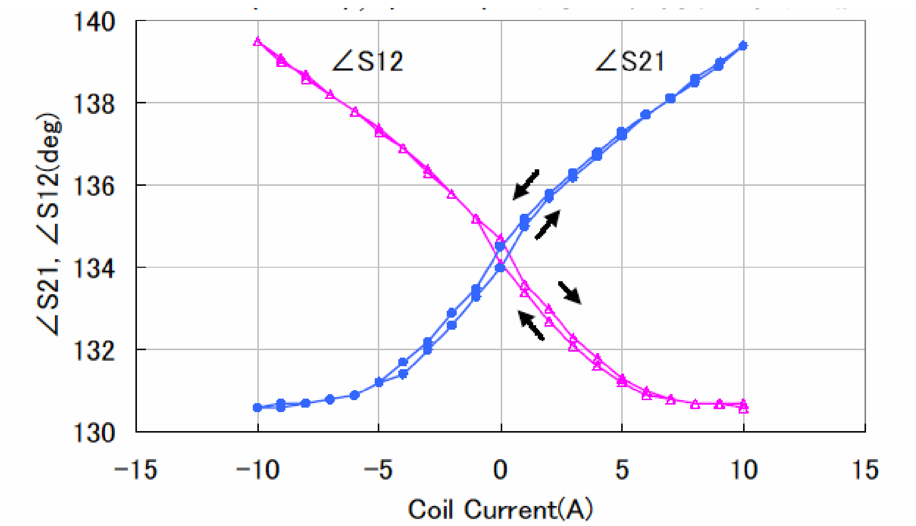
Low power phase shifter

Fed by different generators

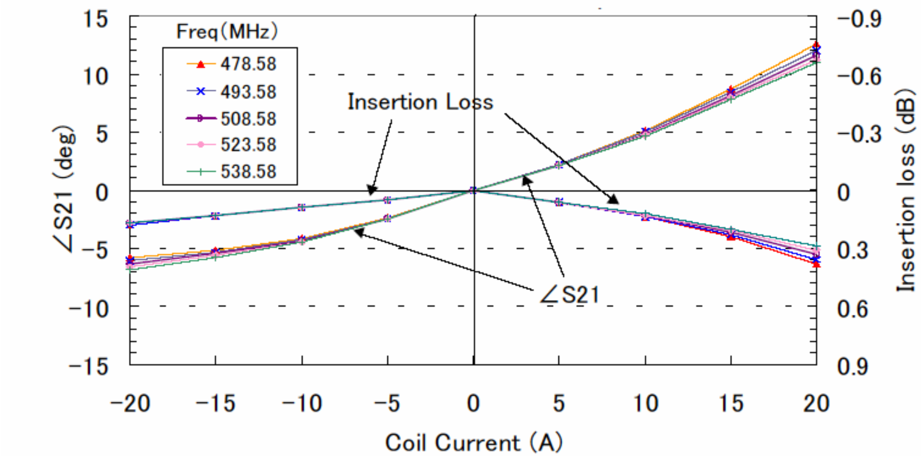
Measured parameters of low power model phase shifter

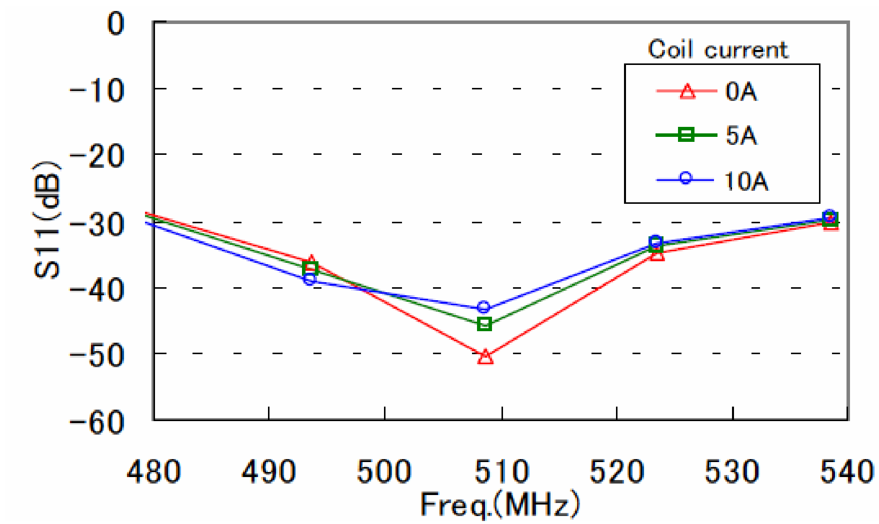
Measured





Calculated





Special Thanks to…

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KEKB SCC Group