

Fast Helicity Switching of Circularly Polarized Light using Twin Helical Undulators

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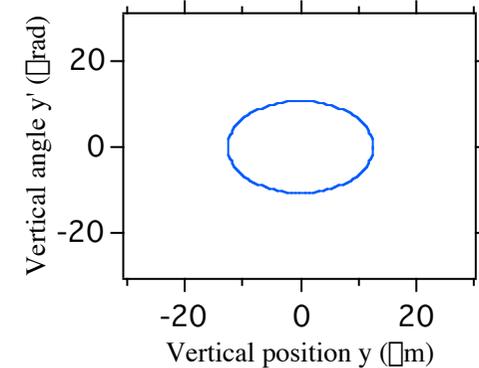
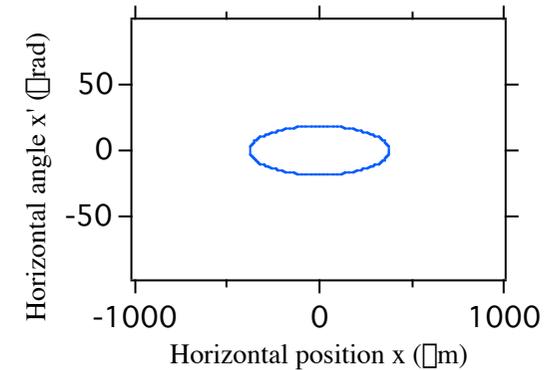
How to switch directions of circular polarization?

- Phase retarder realized in X-rays but not yet in Soft X-rays.
- Change polarization in one undulator

Helical undulator



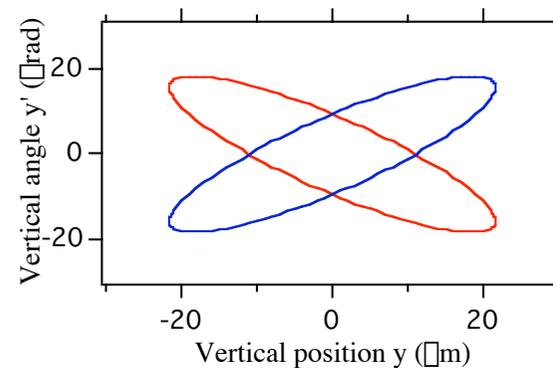
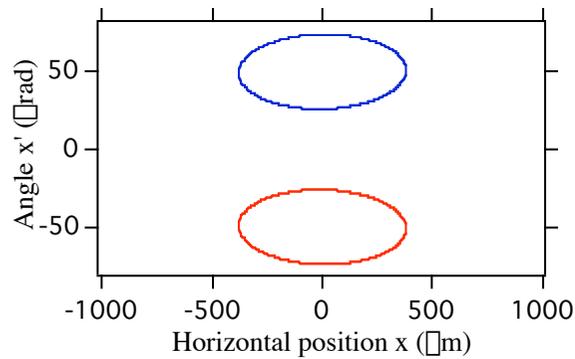
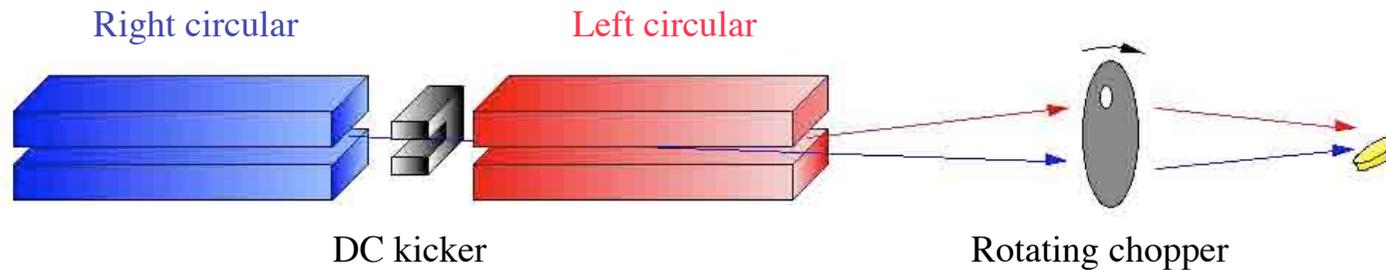
- Two photon sources are identical in phase space.
- Full use of straight section.
- **Effect on electron beam orbit due to eddy current.**



Photon distribution at undulator center (1- σ contour) calculated with SPring-8 parameters.

How to switch directions of circular polarization (cont.)?

- Displace radiation from two undulator and combine them on a sample.

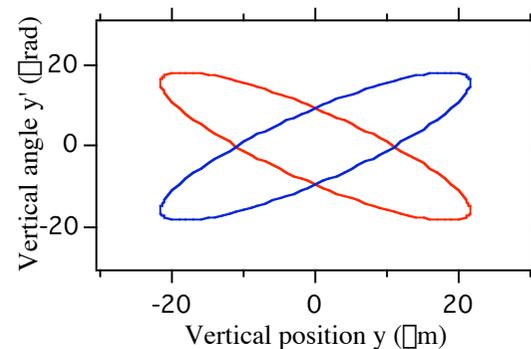
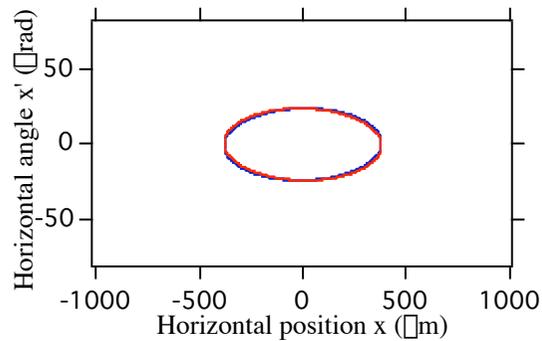
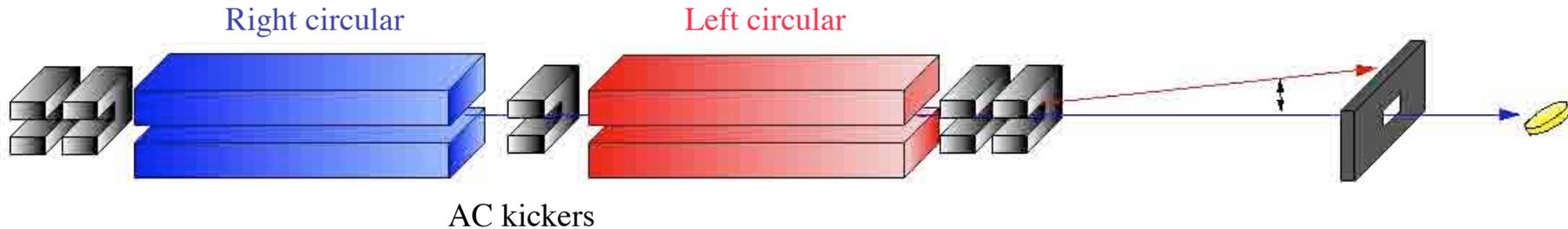


Photon distributions (1- σ contour) of right (blue) and left (red) circular light in the middle of two undulators, displaced by horizontal angle.

- Very fast switching (\sim kHz) by using rotating chopper.
- No effect on the electron beam.
- **Completely different two photon sources.**

How to switch directions of circular polarization (cont.)?

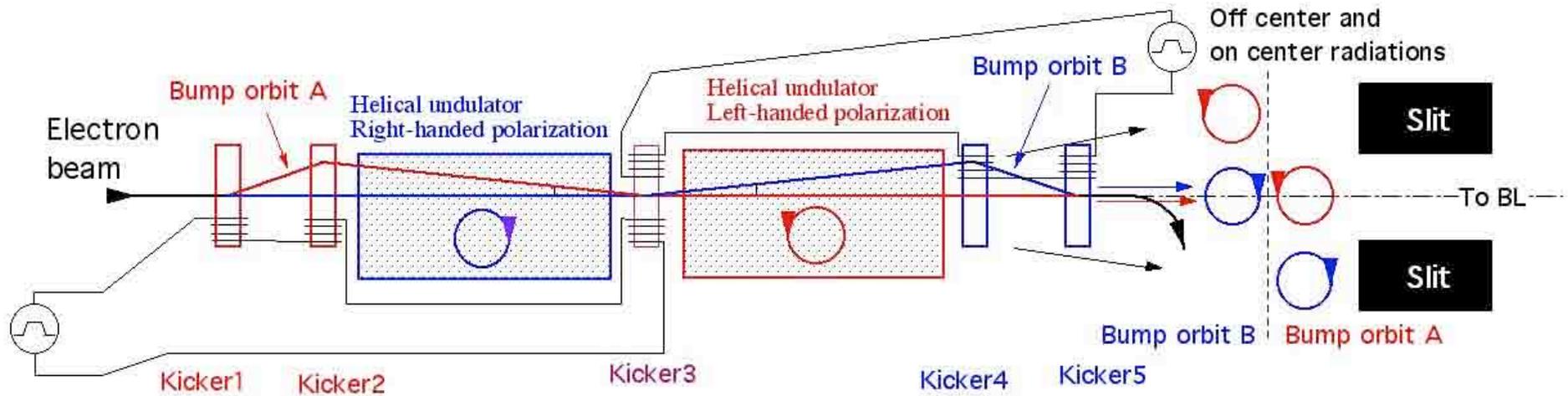
- Switch radiation from two undulators using electron beam orbit bump or undulator gap change.



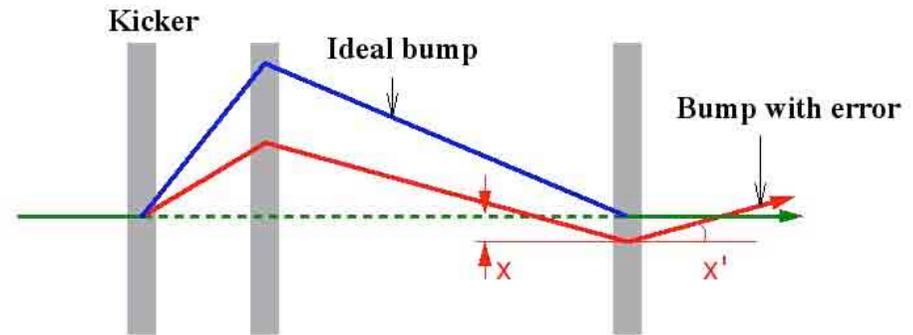
Photon distributions (1- σ contour) of right (blue) and left (red) circular light in the middle of two undulators, direction of polarization is periodically switched by AC kickers.

- Partially overlapped distribution.
- Can reduce eddy current by using ceramic chambers.
- Relatively fast switching (10~100Hz).
- Separate function of switching from undulator gap

How to reduce electron beam orbit distortion (COD)?



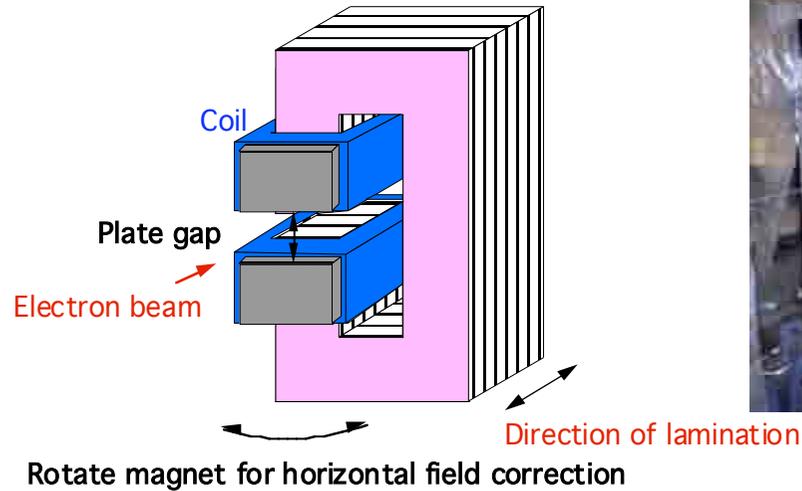
Maximum kicker field ~ 0.12 T.
 Right and left circular beams are separated by ~ 0.2 mrad.



In order to close the triangular orbit bump,

- **three kicker magnets are connected in series** for temporal synchronization.
- same kicker dimension and field strengths are adjusted by number of coil turns.
- kicker core is made of **laminated permalloy** which has low remanent field and high permeability.

In-situ alignment of the kicker field



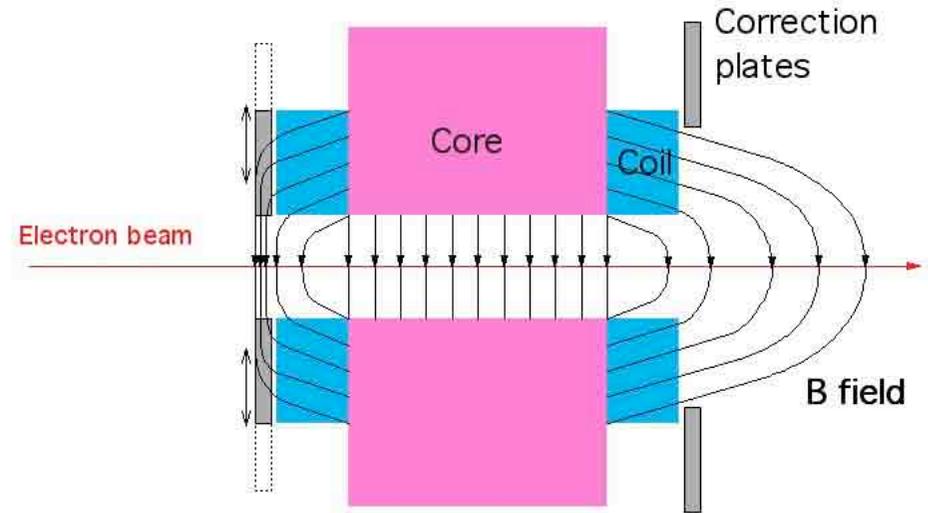
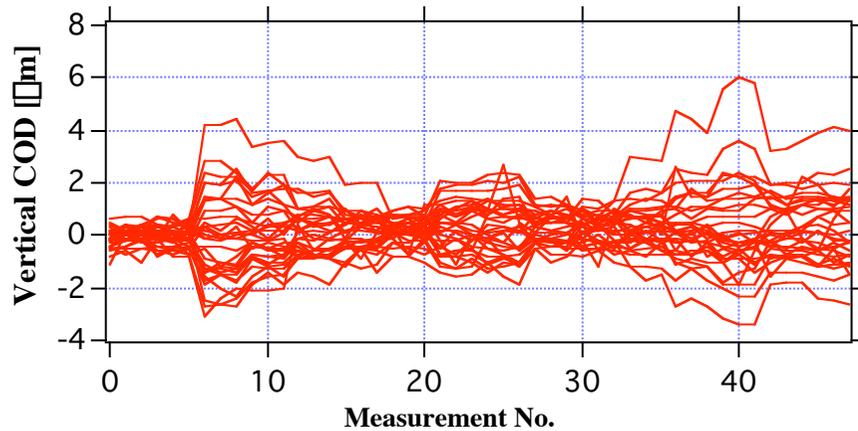
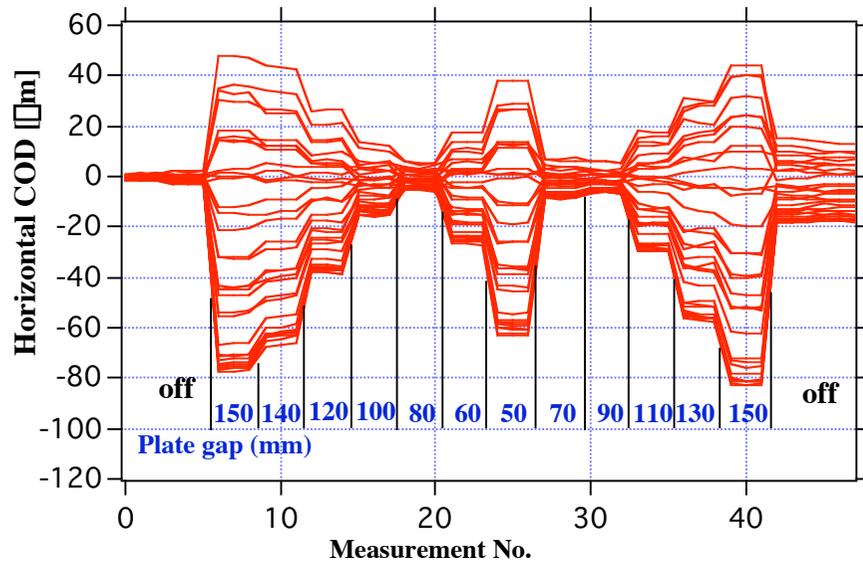
Straight section of SPring-8 BL25SU

- **Vertical DC field error** is adjusted by correction plates instead of shims.
- **Horizontal DC field error** is adjusted by tilting kickers.
- **AC field error** is corrected by air-core coils.



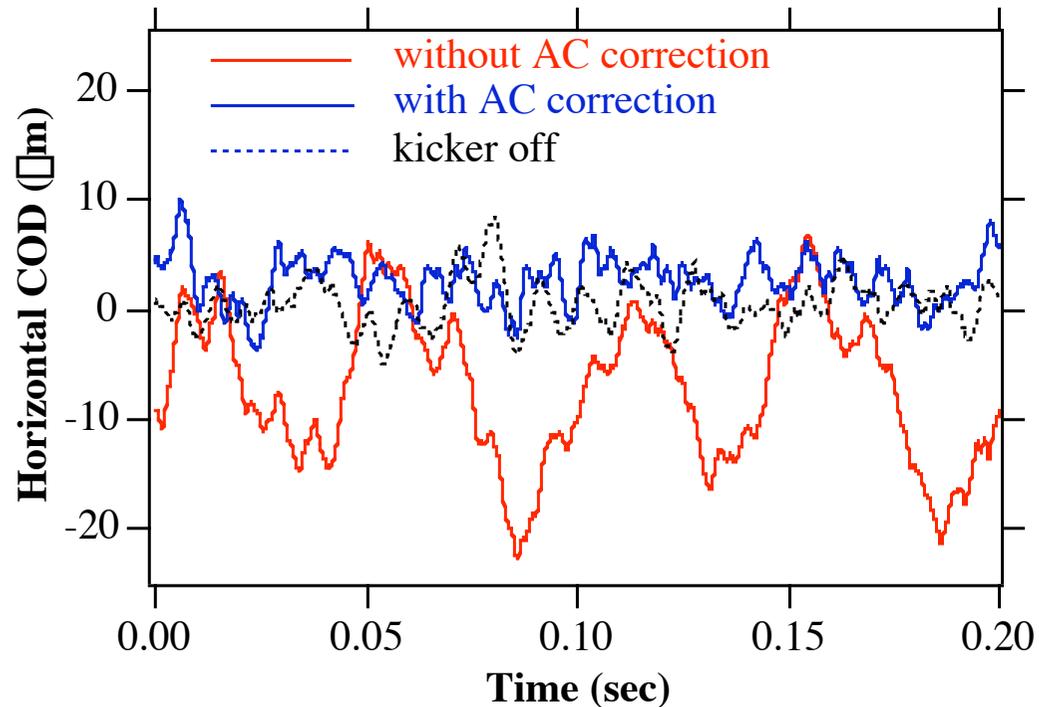
- Ceramic chambers are used at the locations of kicker magnets to reduce eddy current.

In-situ alignment of DC field



Electron beam movement, caused by DC kicker field, as a function of the gap between correction plates (silicon steel). Data are collected using many RF-BPMs distributed around the ring.

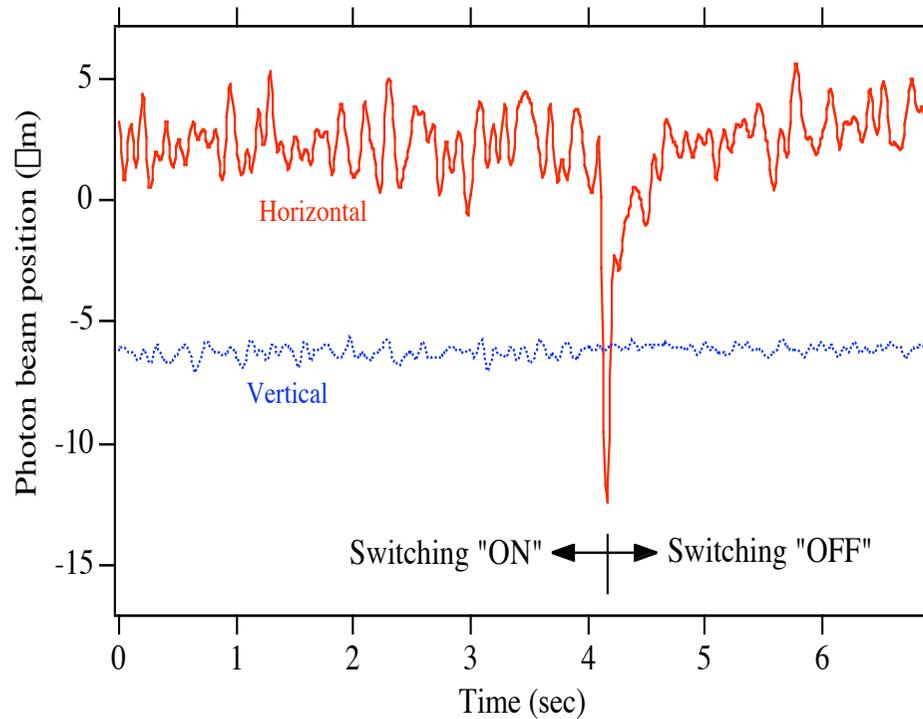
In-situ alignment of AC field



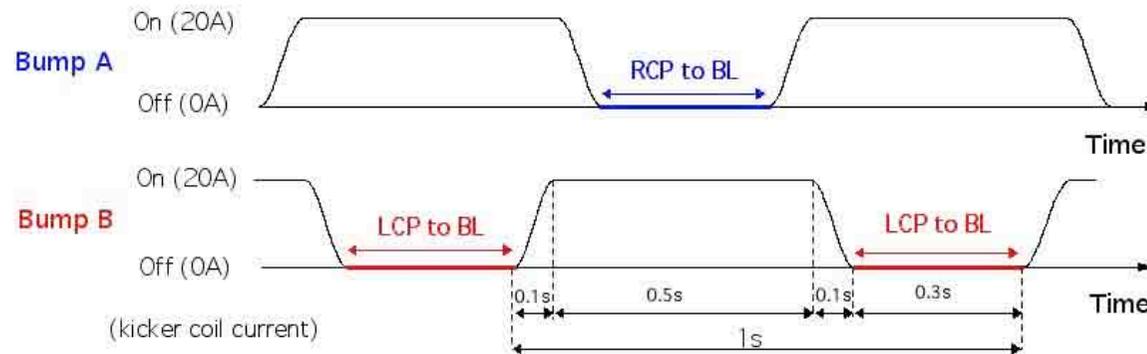
Kicker is operated by 10 Hz sinusoidal current pattern.

- AC field error, mainly due to the eddy current, is corrected using two pairs of air-core coils (horizontal and vertical) in order to cancel 1st and 2nd field integral errors.
- Correction current tables are made from measured CODs (**feed-forward**).

Orbit movement (COD) measured with X-BPM (1 Hz)

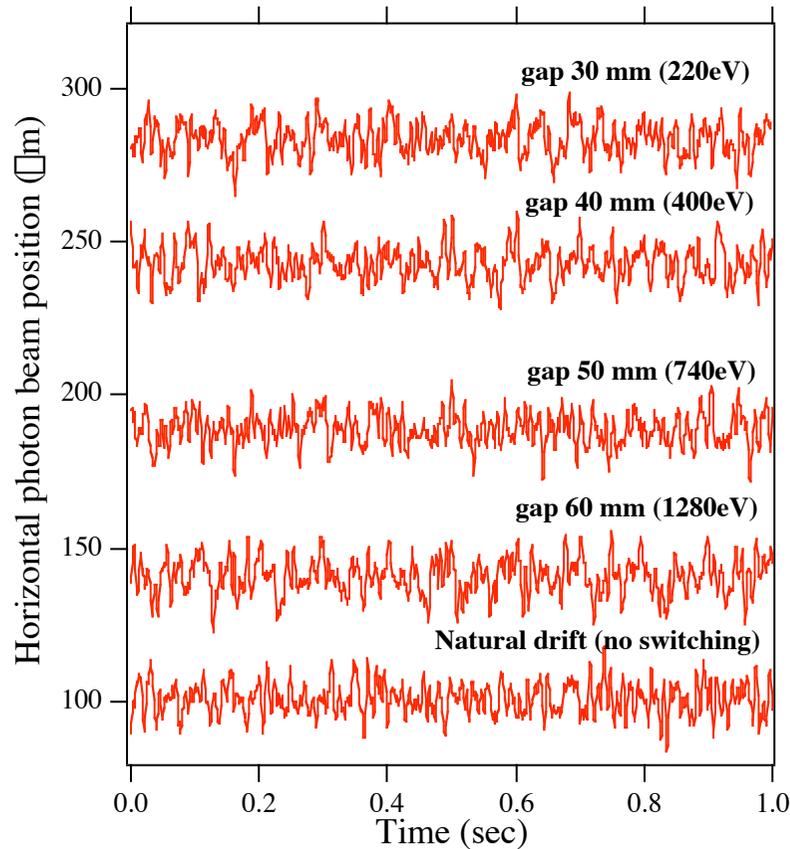


Movement of the electron beam orbit was measured using X-BPMs installed 20 m away from the center of ID straight sections. Several X-BPM locations are picked up for the measurement considering phase of the beta function. Spike of horizontal beam position at center is intentionally added to show the time of switch "OFF."

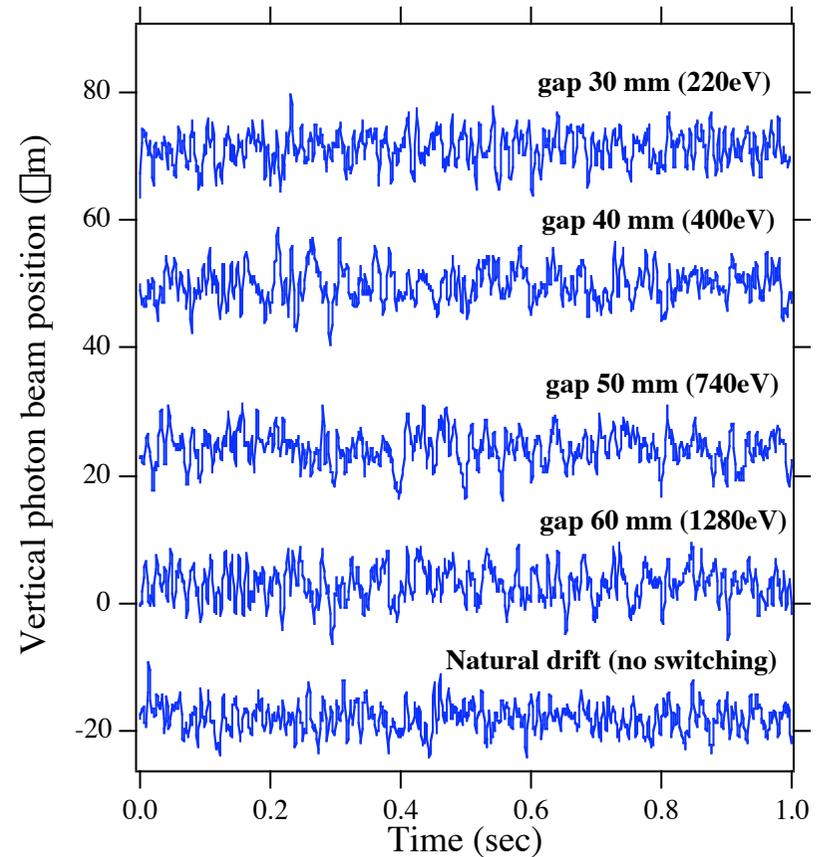


1 Hz trapezoidal pattern
(0.3 sec flat-top)

Orbit movement (COD) measured with X-BPM (10 Hz)



Horizontal beam movement



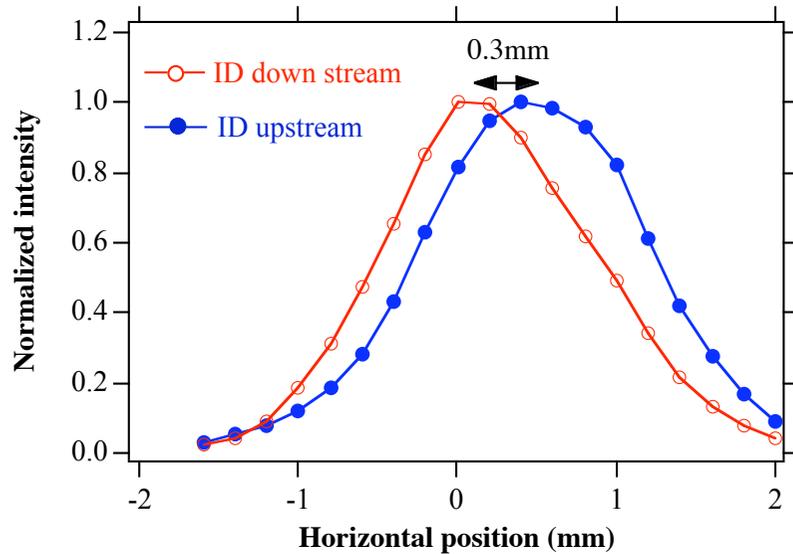
Vertical beam movement

Switching pattern is 10 Hz sinusoidal, positions of each gap are intentionally displaced for clarity.

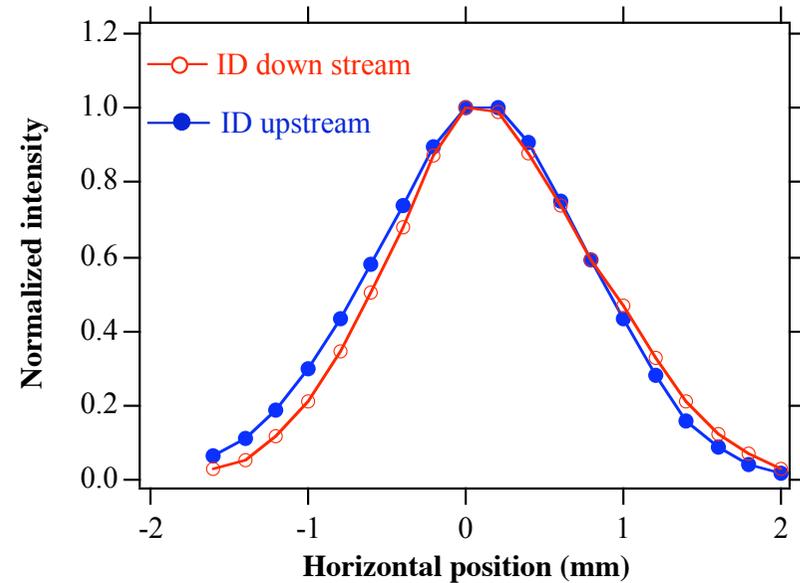
Photon energy can be scanned without interrupting the polarization switching.

CHECK characteristics of radiation (1)

Radiation axes of two undulators



Before correction



After correction

ID radiation measured by a mirror drain current with scanning a FE slit (0.28mmH x 1.0mmV) horizontally. During the measurement, polarization was switched by 1 Hz.

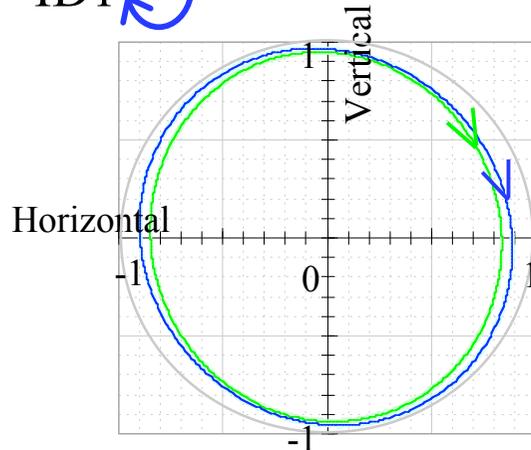
Radiation axes of two undulators can be adjusted by kicker operating current.

CHECK characteristics of radiation (2)

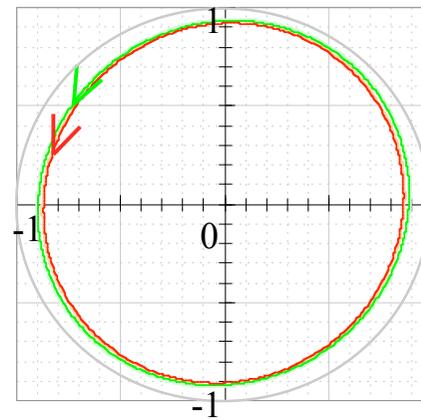
Degree of polarization

Polarization Ellipse at 398.6eV

ID1 



ID2 



LP : Degree of Linear Polarization
 CP : Degree of Circular Polarization
 δ : Azimuth of Ellipse

Measured by ellipsometry
 with Sc/Cr phase shifter
 and polarizer

by H.Kimura and T.Hirono

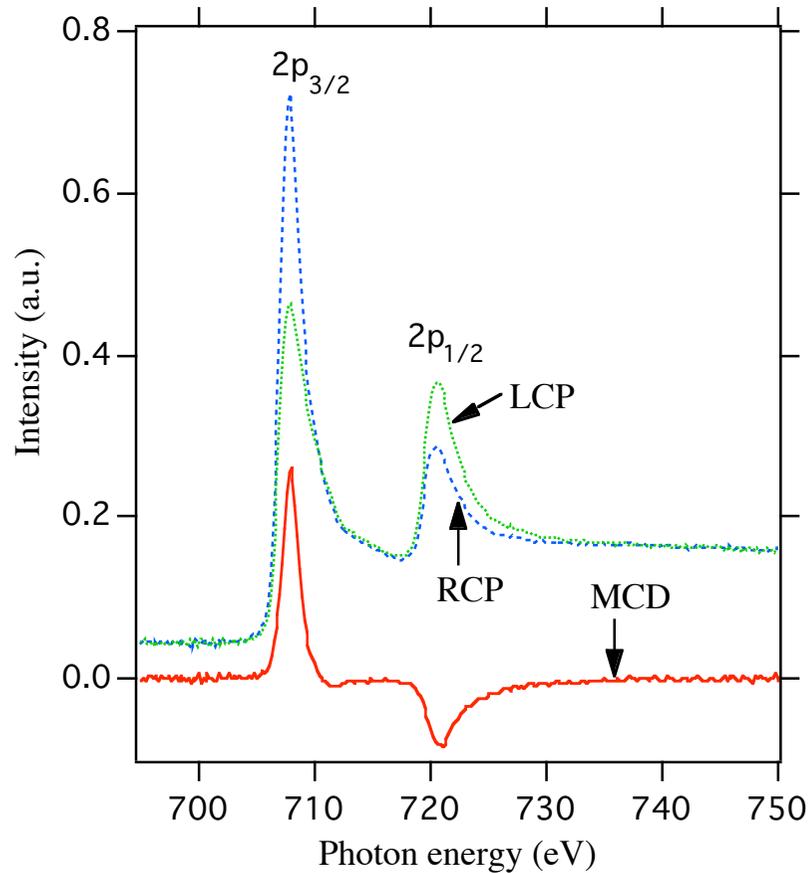
LP : 0.11 ± 0.01		0.09 ± 0.01
CP : 0.94 ± 0.01		0.97 ± 0.01
δ : $100 \pm 1 \text{deg}$		$111 \pm 1 \text{deg}$
Static radiation		Helicity switch

LP : 0.058 ± 0.003		0.063 ± 0.003
CP : -0.94 ± 0.01		-0.92 ± 0.01
δ : $64 \pm 2 \text{deg}$		$72 \pm 2 \text{deg}$
Static radiation		Helicity switch

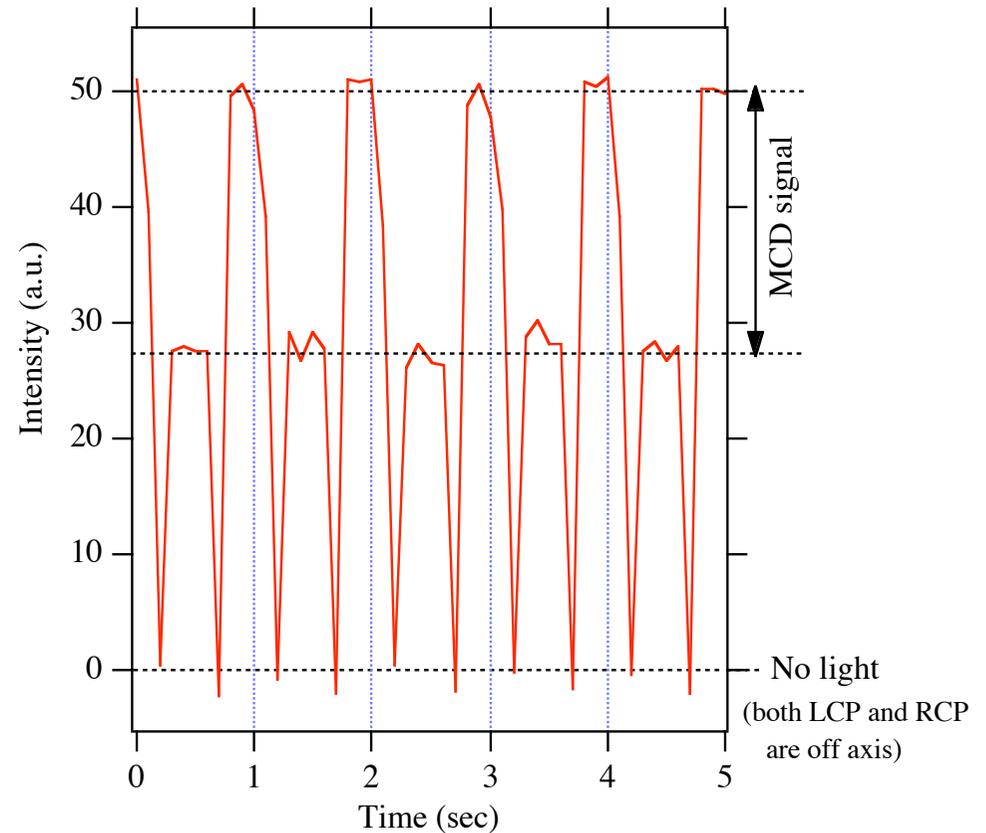
Circular polarization is measured by MCD (T. Muro et al. WED-P10.3) and a multilayer polarimeter (H.Kimura and T.Hirono et al. MON-P2.3).

No degradation of degree of polarization due to switching.

MCD measurements (Fe 2p) using helicity switched light



Spectra of Fe 2p photo-absorption, signals are normalized with respect to incident flux.



Variation of photo-absorption as a function of time

Summary

- No significant effect on electron beam orbit.
- No degradation of circular polarization due to switching.
- Time of MCD measurements reduced by 1/3.
- Undulator gap change for photon energy scan (for example 200~1000 eV) without interruption of switching.