Development of the non-invasive beam size monitor using ODR

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Introduction

For the ultra-low emittance and high intensity electron beam required by Linear Colliders and X-ray FEL,
conventional beam diagnostics (OTR monitor ,solid wire scanner, etc.) are not applied to such beams because of the target destruction.
Therefore non-invasive beam diagnostics is necessary techniques for such accelerators.

Because of non-invasive nature, Diffraction radiation(DR) is one of candidates for application to non-invasive beam diagnostic.
However a very little experimental investigations exited.
Those experiments are measurements of coherent diffraction radiation(λ~1mm),
incoherent diffraction radiation with visible light region(Optical Diffraction Radiation :ODR) hadn't been observed.

Since 2000, we have performed ODR experiments using low emittance electron beam extracted from KEK-ATF damping ring.
At first stage experiments,
we confirmed basic characteristics of ODR from the single edge target.
(T. Muto *et al.* , Phys. Rev. Lett 90,104801(2003))

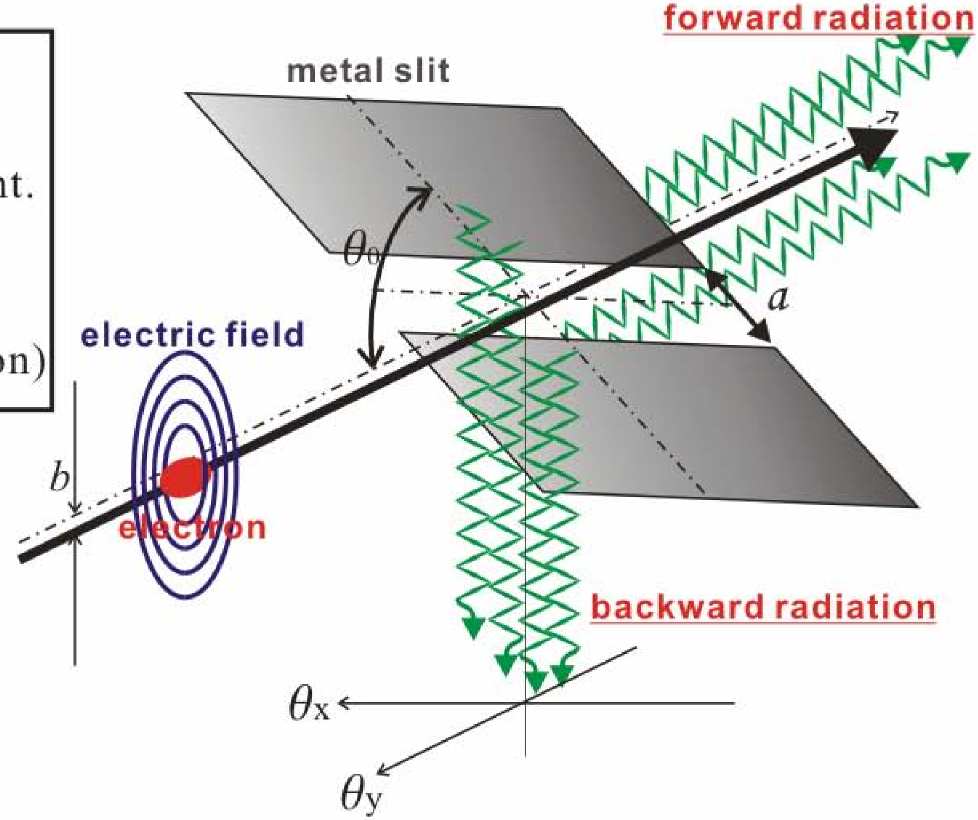
Now we have developed the beam size monitor using ODR.

Principle of the ODR monitor

Optical Diffraction Radiation

The ODR appears
when the charged particle passes
near media with different dielectric constant.

ODR is emitted to two direction
- along the particle (forward radiation)
- direction of reflection (backward radiation)



Beam size measurement using ODR

use the interference of ODRs from two halves of the slit target

Features of ODR monitor

- non-invasive
- one-shot measurements
- large observation angle
- good time resolution

Principle (Cont.)

Angular distribution of the vertical polarization component of ODR

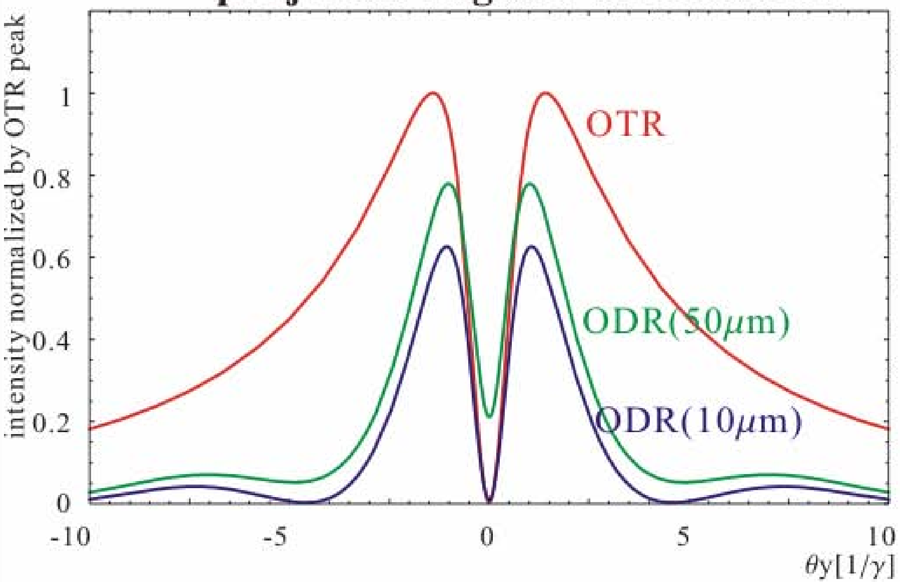
$$\frac{dWy}{d\omega d\Omega} = \frac{\alpha\gamma^2}{2\pi^2} \frac{\exp\left(-\frac{2\pi a \sin\theta_0}{\gamma\lambda}\sqrt{1+t_x^2}\right)}{1+t_x^2+t_y^2} \left\{ \exp\left(\frac{8\pi^2}{\gamma^2\lambda^2}\sigma_y^2(1+t_x^2)\right) \cosh\left(\frac{4\pi b}{\gamma\lambda}\sqrt{1+t_x^2}\right) - \cos\left(\frac{2\pi a \sin\theta_0}{\gamma\lambda} t_y + \psi\right)\right\}$$

$$t_{x,y} = \gamma\theta_{x,y} \qquad \psi = \arccos\frac{1+t_x^2-t_y^2}{1+t_x^2+t_y^2}$$

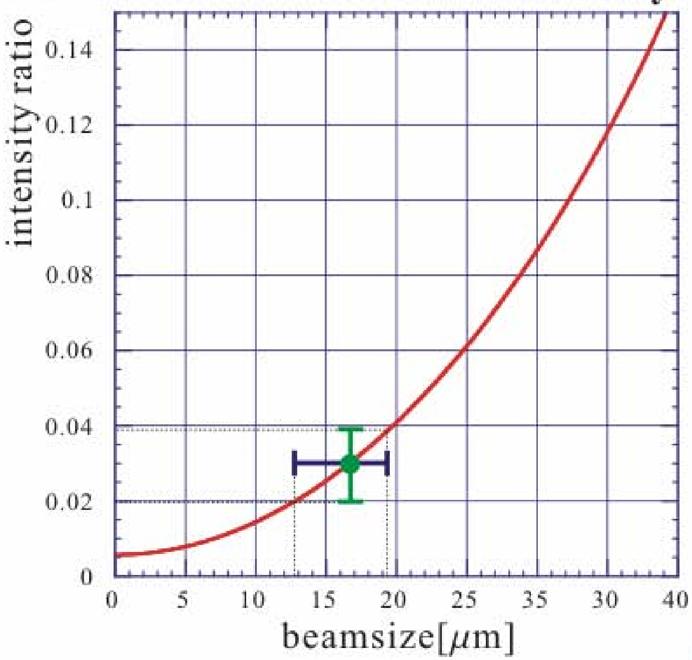
(assume the beam has Gaussian distribution)

In order to increase the signal, we take integrate to the horizontal angle

projected angular distribution

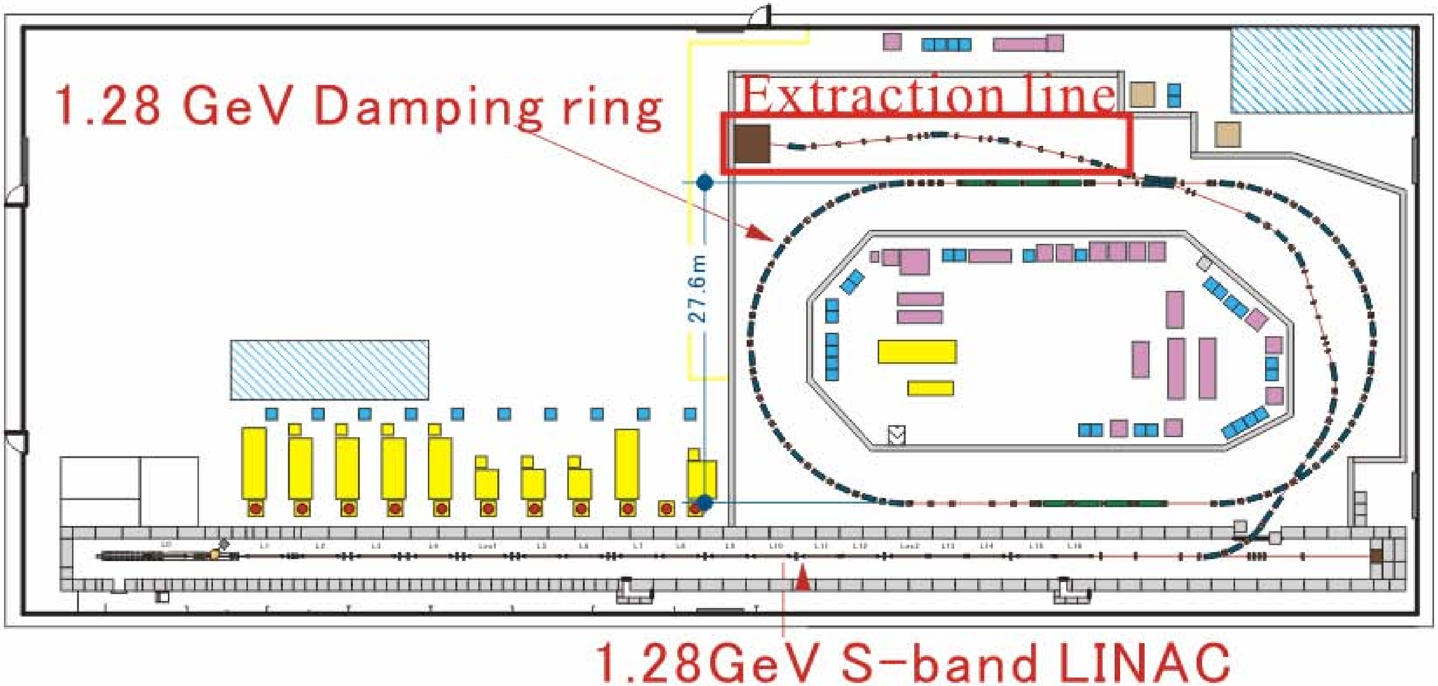


beam size vs minimum-to-maximum intensity ratio



ODR ATF

KEK-ATF (Accelerator Test Facility)



KEK-ATF parameter

energy 1.28GeV($\gamma \sim 2500$)

emittance vertical $\sim$ 5 pm rad

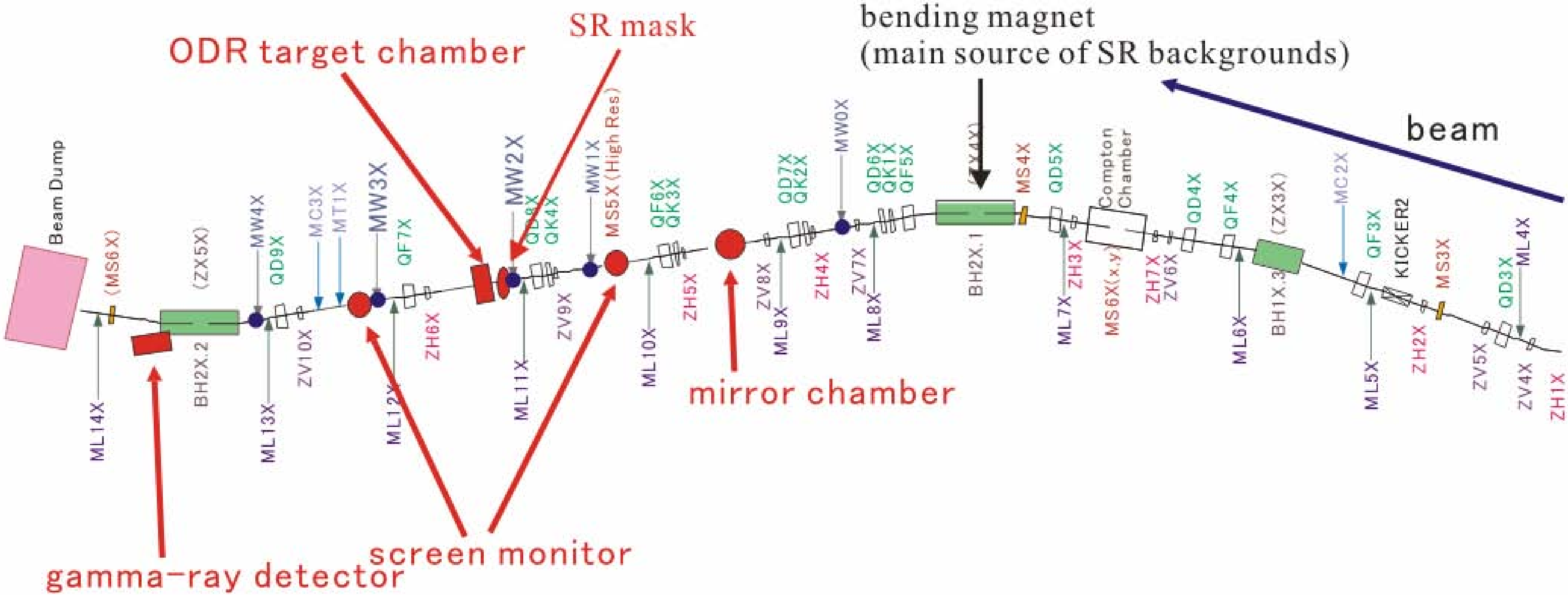
horizontal $\sim$ 1nm rad

bunch length 20ps

intensity

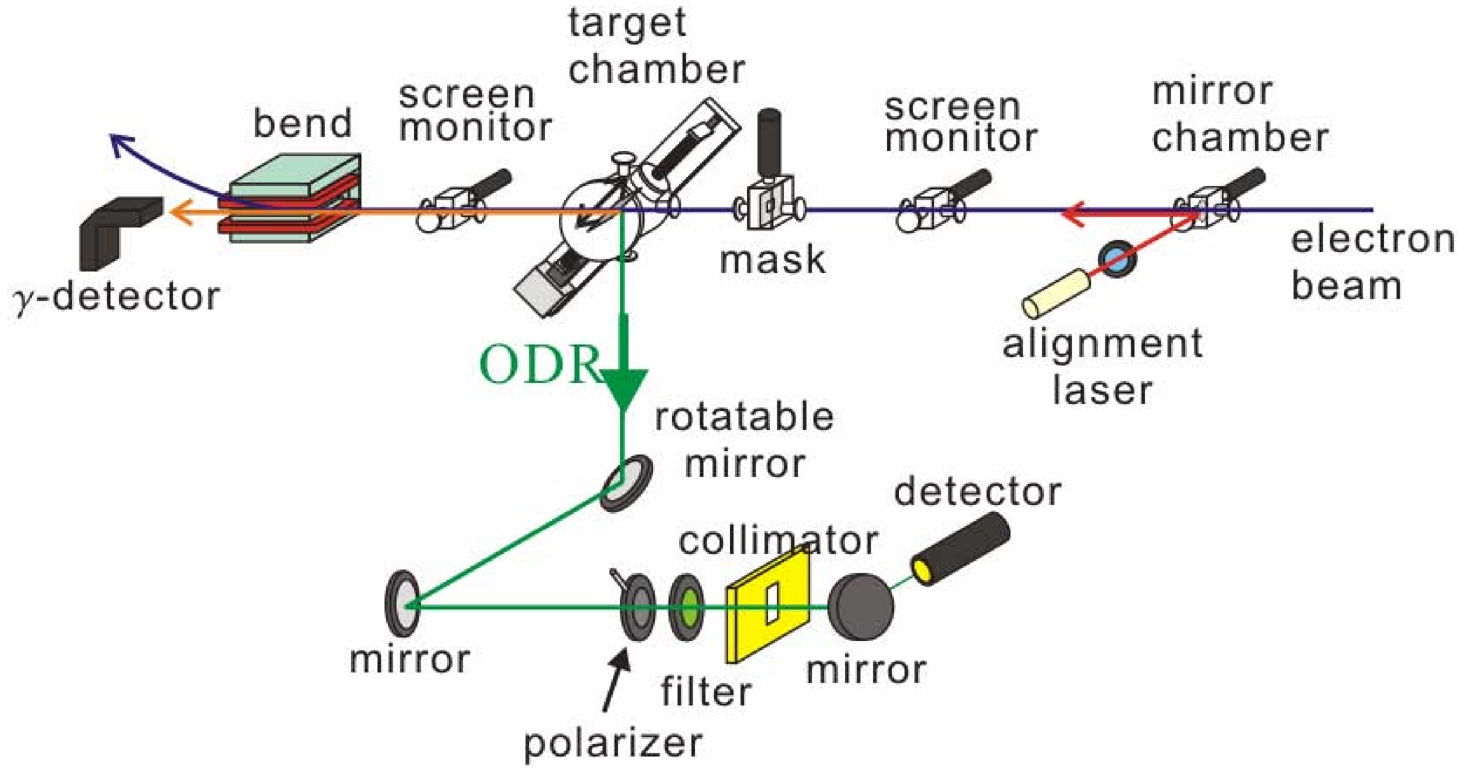
1.2×10^{10} electrons/bunch

Layout of the extraction line



The emittance can be measured by 5 wire scanners.
At the ODR measurements,
emittance measurements was done.
Using measured parameters,
the optics for ODR measurements was calculated by SAD.

Schematic view of the experimental set up

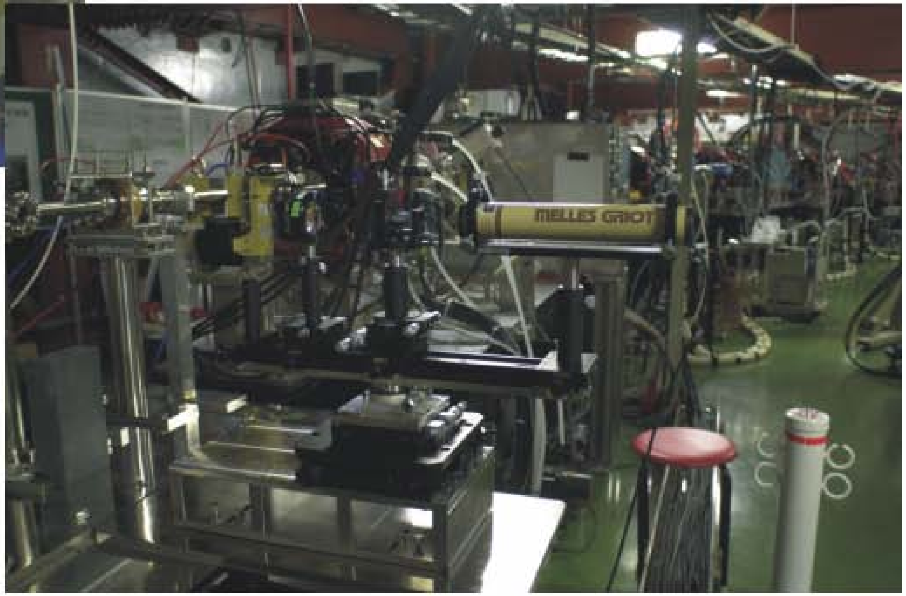


collimator size: v 0.2(=0.142γ^{-1})x h 24(=15.2γ^{-1})mm
rotatable mirror accuracy : vertical=19μrad, horizontal=35μrad
target position read accuracy: 0.5μm
filter wavelength region : 550±20nm
light detector : PMT(Hamamatsu H1161)
γ-detector : Air Cherenkov counter
alignment accuracy : <100μm(position) , <42μrad (angle)

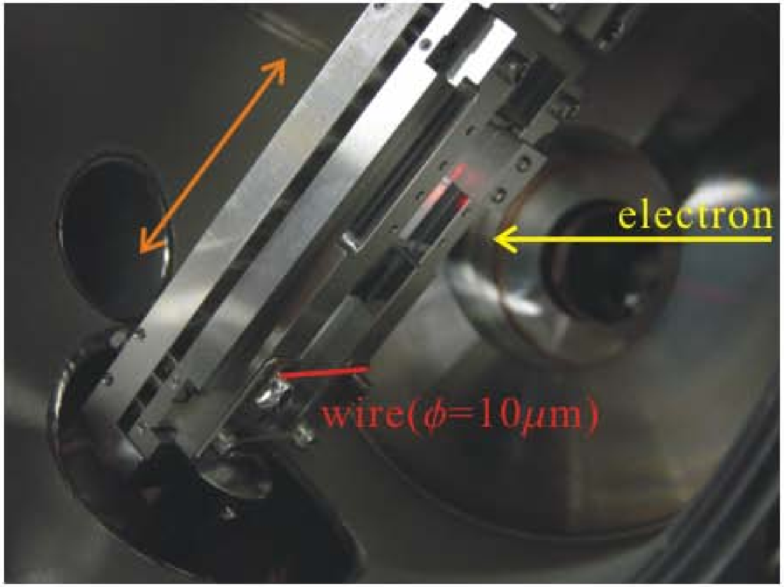
the ODR chamber and the alignment laser

target chamber

alignment laser

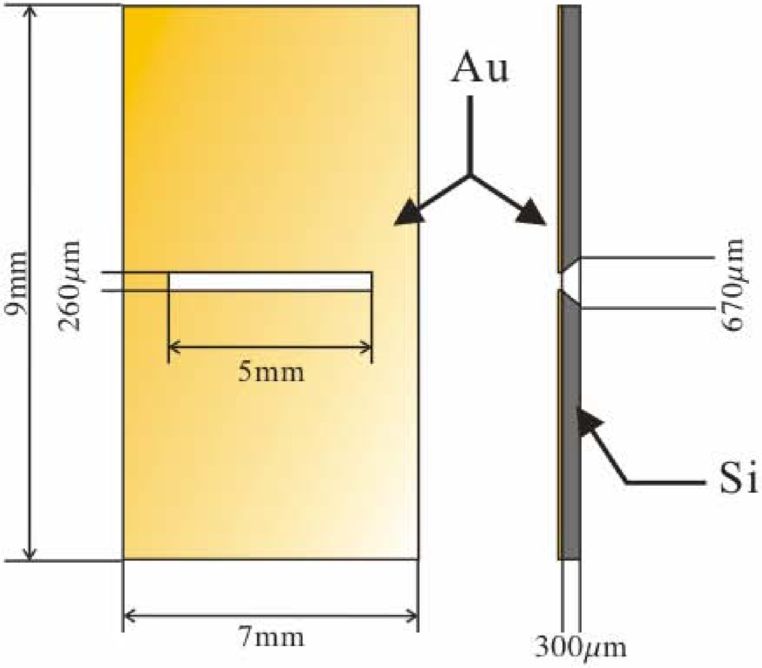


Target and wire



target property	
silicon thickness	300μm
gold foil thickness	~1μm
edge uniformity	1−2μm
average roughness	20nm
Maximum roughness	150nm

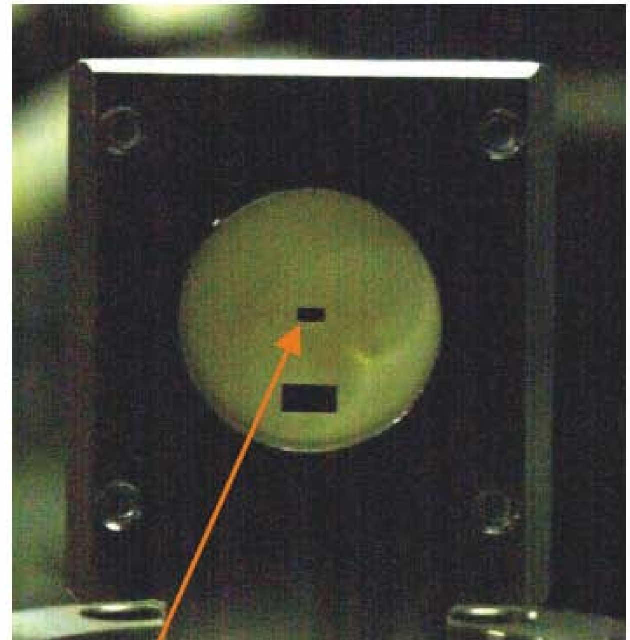
slit target



Silicon wafer covered with gold

SR mask

To avoid the contribution of synchrotron radiation(SR), we installed "SR mask" in front of the target chamber.



1x2mm hole on the ceramic plate

poster : THPLT067

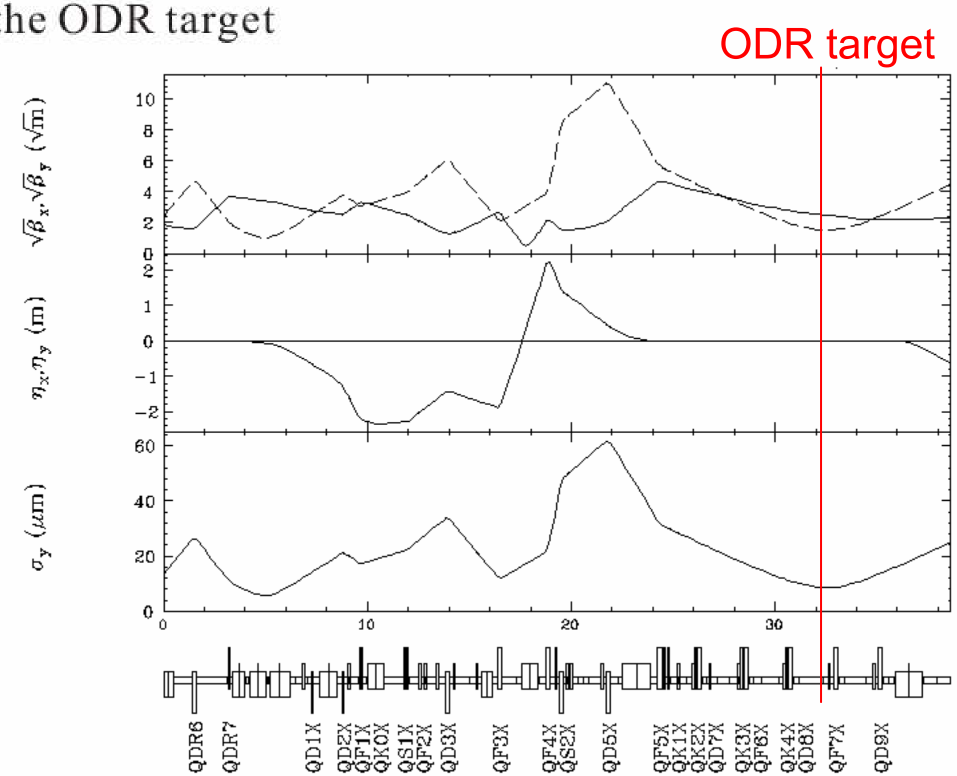
Optics and Wire-scanning

In order to avoid SR background,
the optics is all most quad and steer magnets after last bending magnet is turn off.

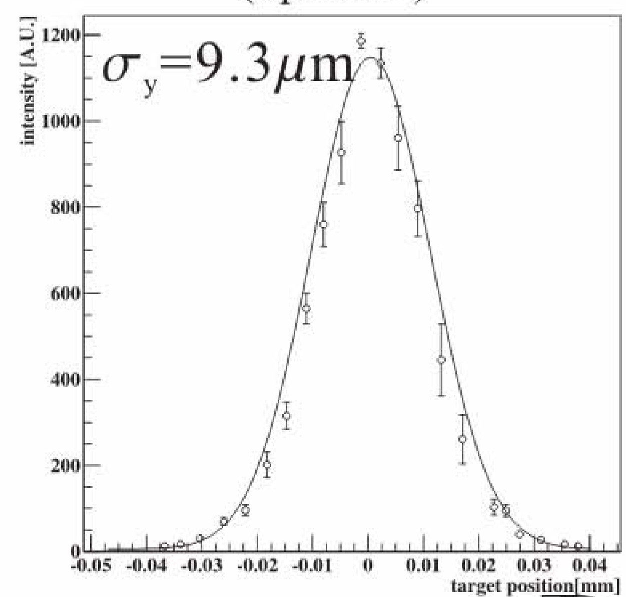
three different optics calculated by SAD were prepared

- σ_y=9μm (optics A)
- σ_y=15μm (optics B)
- σ_y=25μm (optics C)

at the ODR target

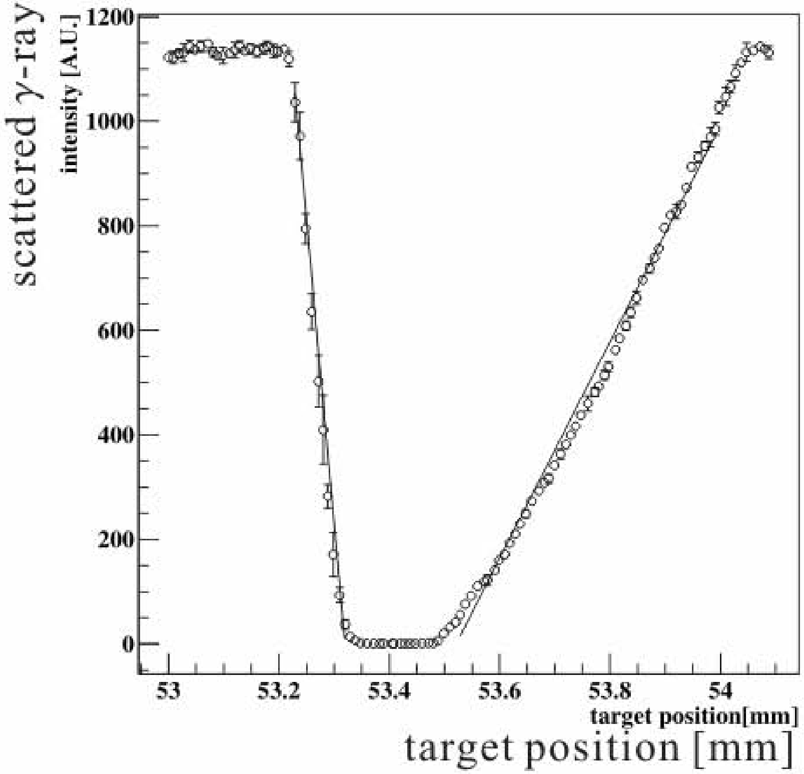


beam size measured
by wire scanner
(optics A)



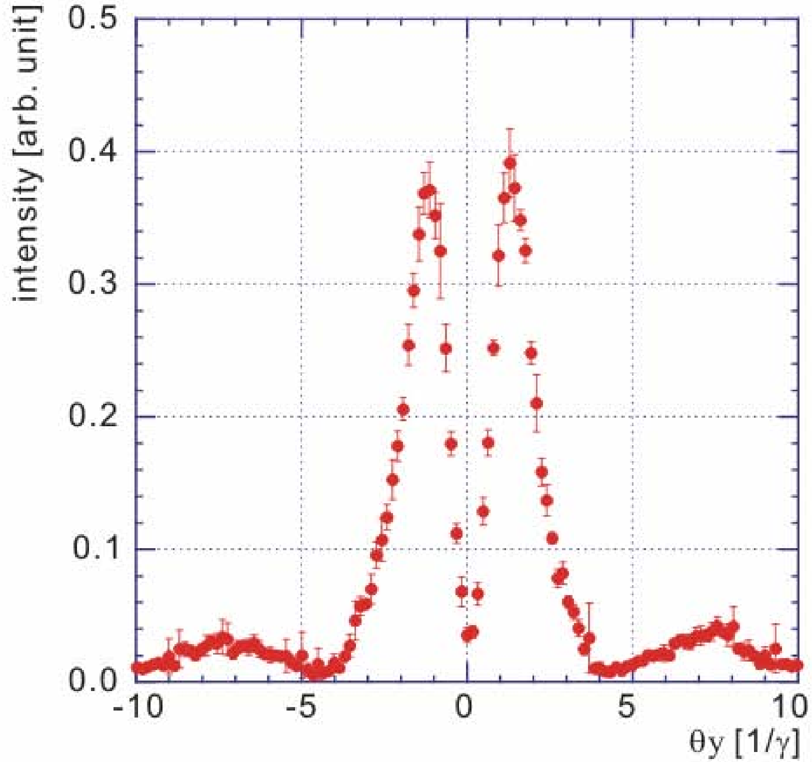
Results

Target scan



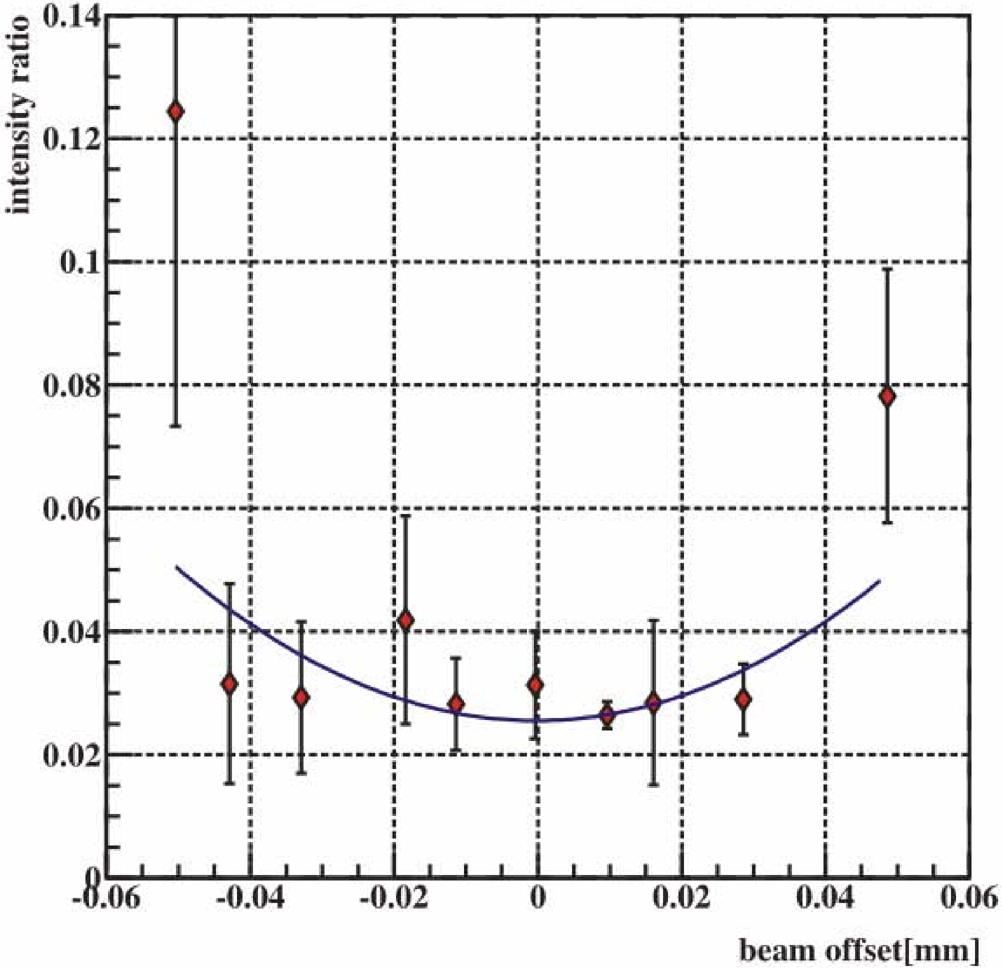
by this scan, slit center was obtained

ODR angular distribution



clear interference pattern by ODR was observed.

Minimum-to-maximum ratio vs the target position (optics B)

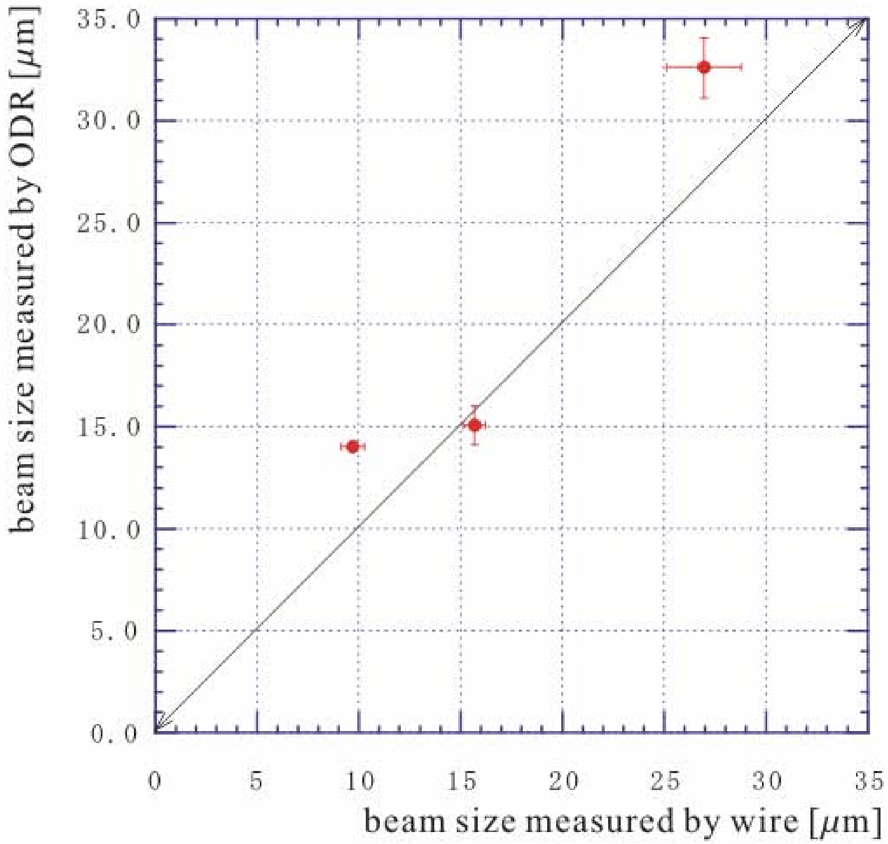


The solid line represents the parabolic fit.

From parabolic fit minimum-to-maxmum intensity ratio was obtained.

Only statics error is shown.

The comparison with measurements by the wire-scanning



Beam sizes measured by the ODR monitor has a sensitivity around 20μm electron beam size.

Beam sizes measured by the ODR monitor were larger than measured by wire scanner.

It indicate that there are some systematic errors.

During this measurements, the beam extraction was not stable, because of the extraction kicker's timing jitter.

Summary

- We performed the beam size measurements using ODR.
- The ODR interference pattern from the slit target was observed, and that has a sensitivity to electron beam size.
- From the comparison with beam sizes measured by the wire scanner, theare are some systematic errors.
- During this measurements, the beam orbit was unstable because of kicker. We should need to more intensive study. And in order to increase sensitivity, we will measured ODR with shorter wavelength.