Development of diagnostic systems for ATF operation/experiments

T. Watanabe, ATF

Beam angle monitor via observation of Cherenkov radiation

Applications
- Daily linac operation - observation of dispersion -
- Compton scattering experiment
- Pick-up of a microbunch from microbunch train

etc.

Measurement of microbunches by CTR/CDR* techniques

Applications
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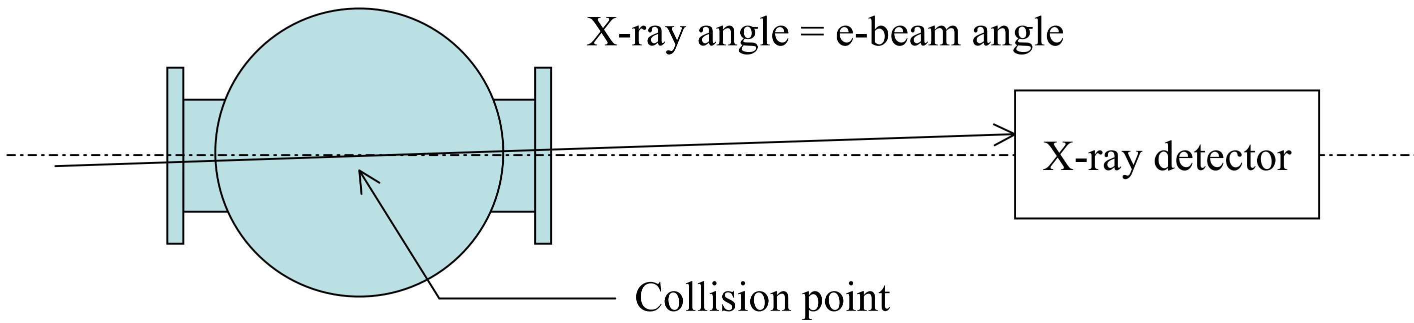
* CTR/CDR : Coherent Transition/Diffraction Radiation

Beam angle monitor - motivation -

Compton scattering experiment

How to know the angle of e-beam?

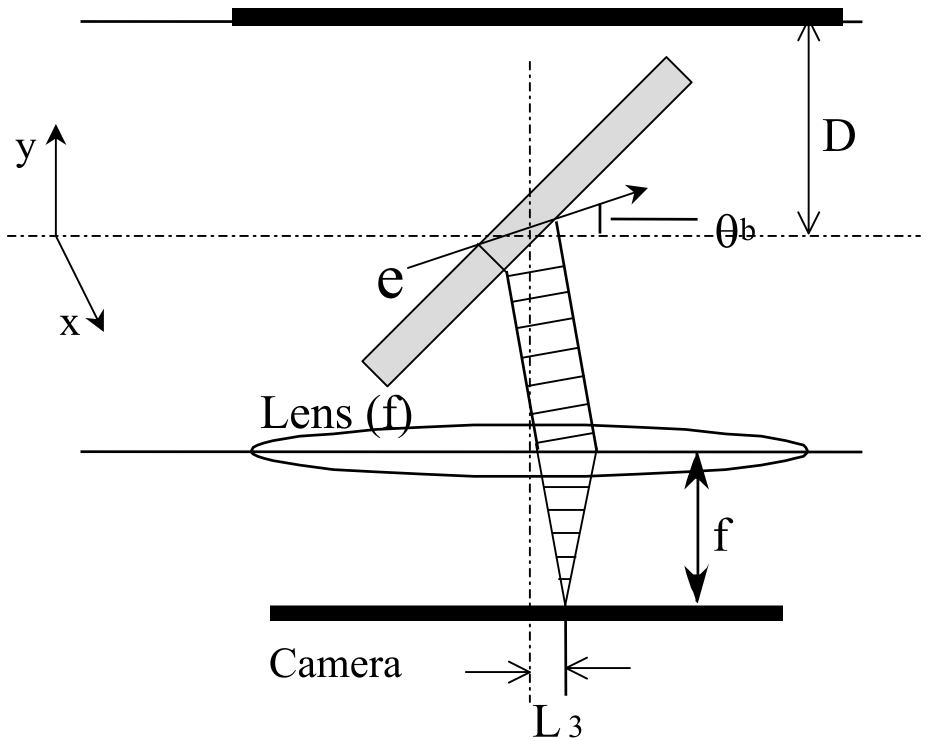


Promising schemes (OTRI, ODTRI, cavity, etc.) have been studied and developed.

- Non-destructive measurement for e-beam/laser
- High resolution
- Energy independence
- Simultaneous observation of beam position/profile
- Small setup (w/o interfering laser/beam optics)
- Easy handling (large number of photons etc.)
- Single shot measurement
- Relative angle measurement against x-ray detector

Cherenkov radiation

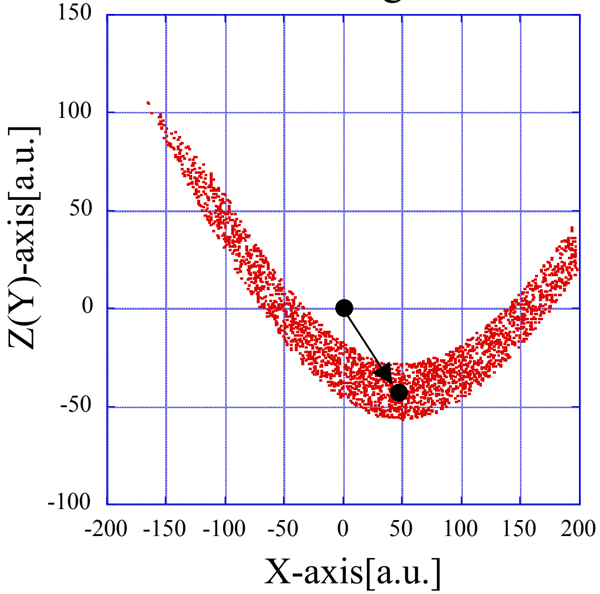
Beam angle monitor - principle -



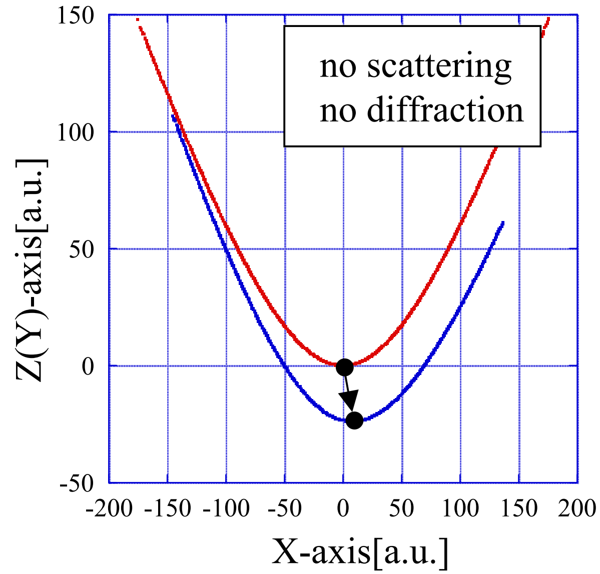
$$L_1 = (D-d)\cdot tan\left(\frac{\pi}{2}-\theta_{ch}-\theta_b\right) \propto d\cdot tan(\theta_{ch}+\theta_b)$$

$$L_3 = f\cdot tan\left(\frac{\pi}{2}-\theta_{ch}+\theta_b\right) \sim f\cdot \theta_b$$

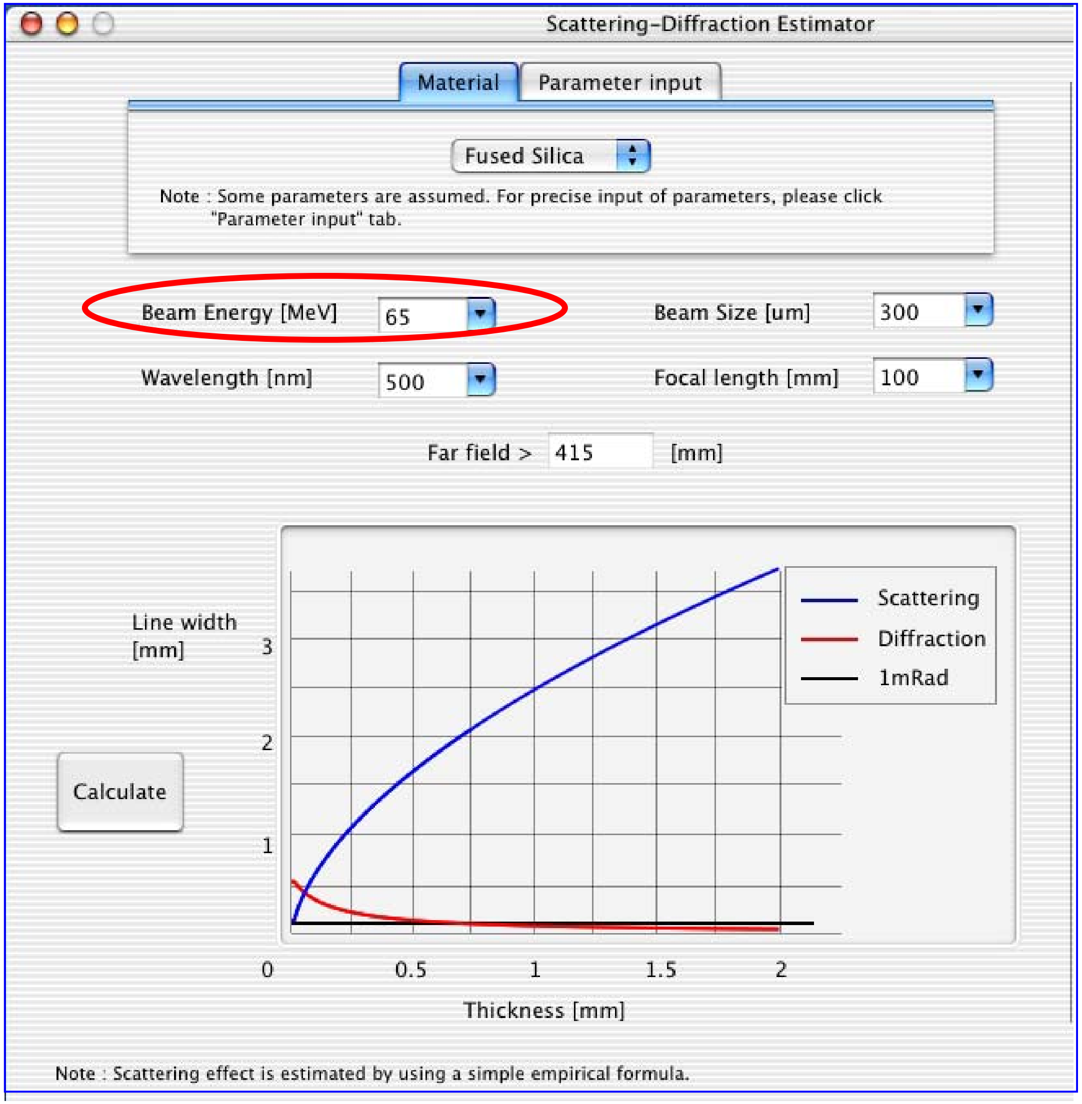
Cherenkov image w/o lens



Cherenkov image with lens



Beam angle monitor - estimation -



Beam scattering
Diffraction

Optimum thickness

65 MeV -> 100um[t]

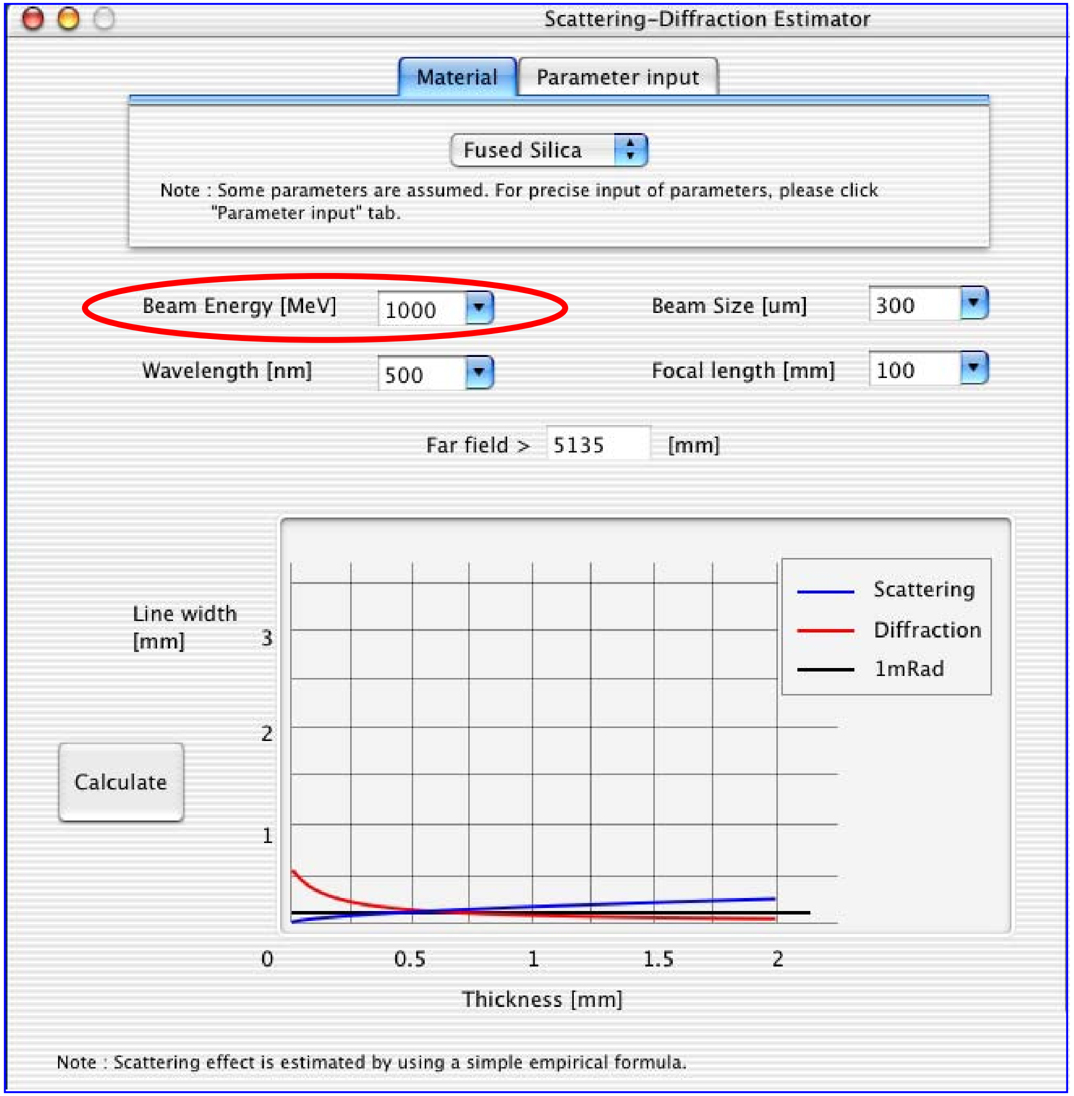
Resolution ~ 0.8mRad?

under assumption that the resolution is 10 times smaller than line width.

~8x10^9 photons / 100 pC

w/o bandpass filter

Beam angle monitor - estimation -



Optimum thickness

1 GeV -> 700um[t]

Resolution
~ 0.1mRad?

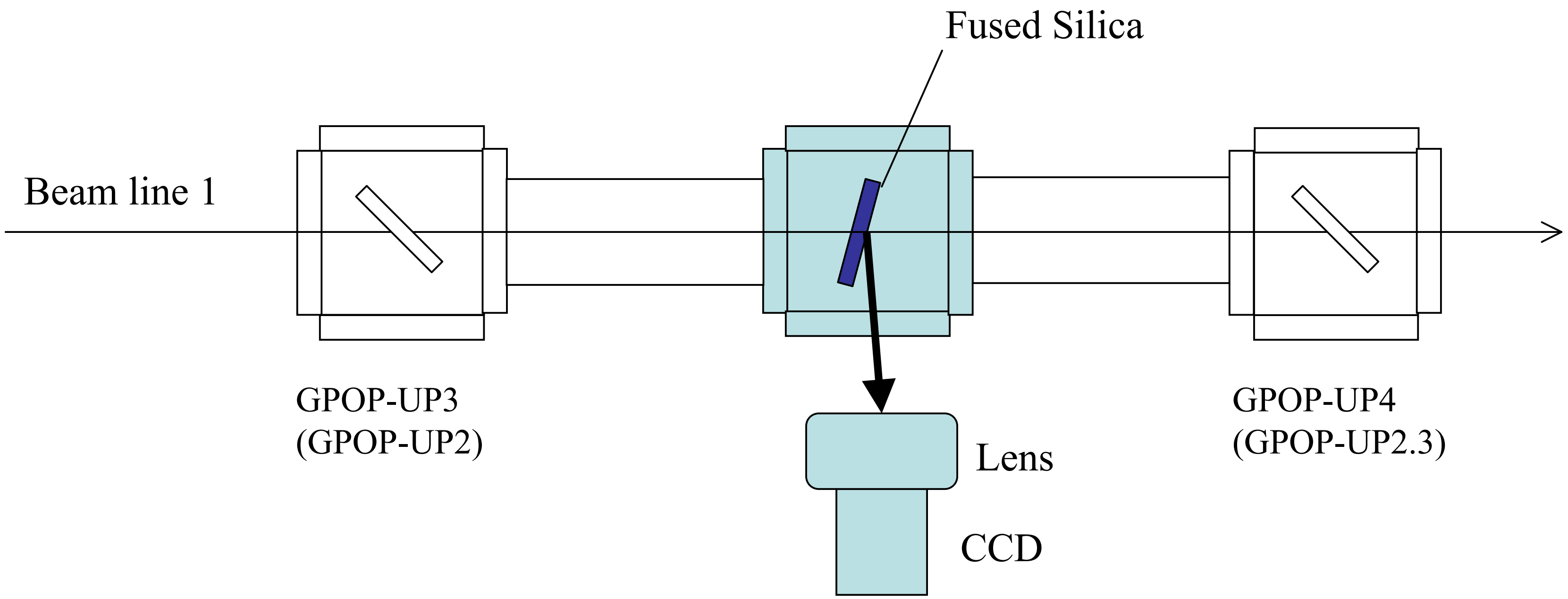
under assumption that the resolution is 10 times smaller than line width.

~ 6 x 10^{10} photons / 100 pC
w/o band-pass filter

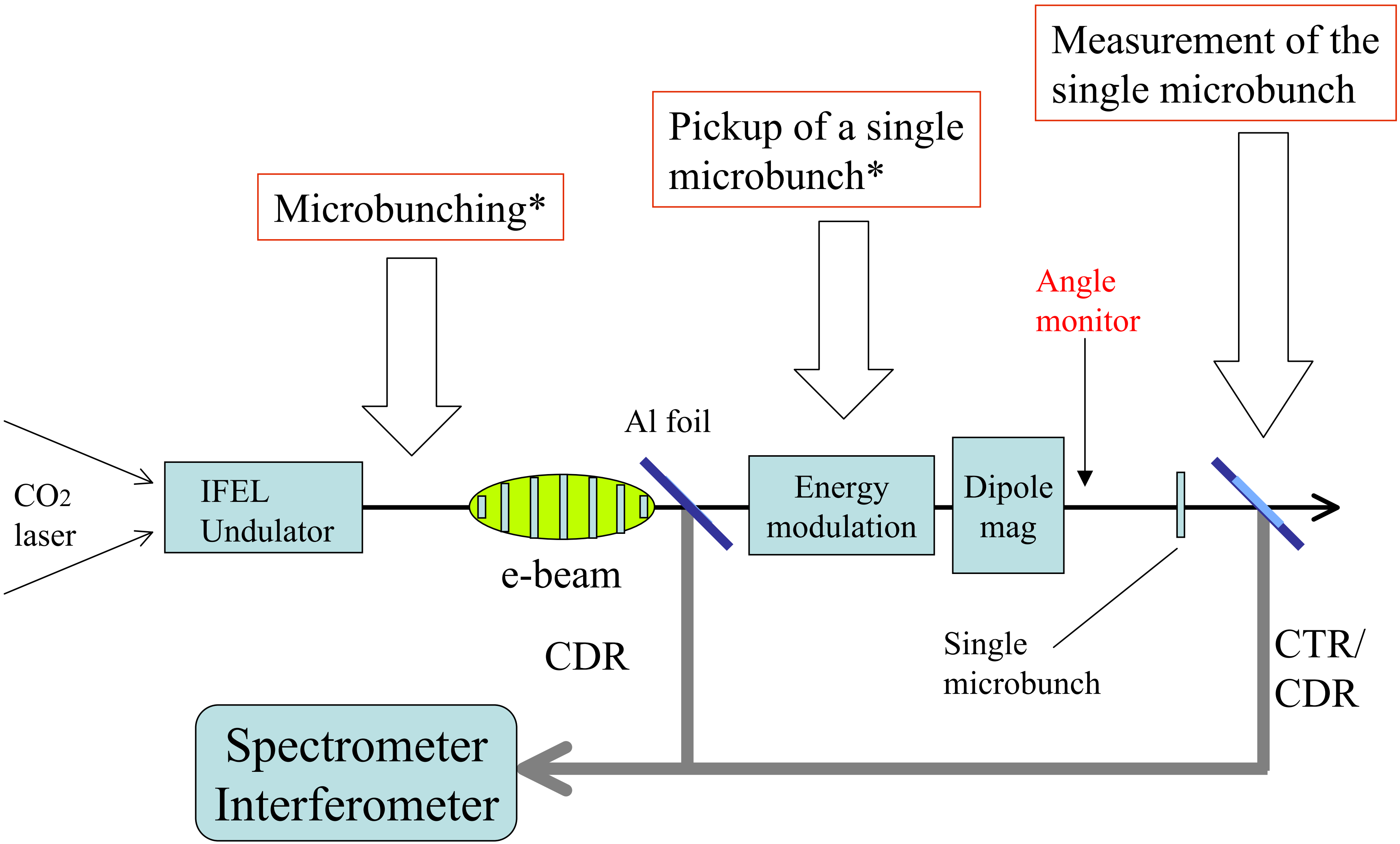
Beam angle monitor - experiment -

Preliminary experiment with 1-2 mm^t fused silica

- Radiation intensity
- Beam scattering
- Diffraction
- Chromatic aberration



Measurements of microbunching



*Vitaly's presentation

Experimental observation and characterization of UR/CTR

UR* → SASE-FEL

[4] A.Tremain et al., PRL (2002) - Gain length, Spectrum
[5] A.H. Lumpkin et al., PRL (2002) - Sidebands, Spectrum
[6] A. Tremain et al., PRE (2002) - Bunching factors
[7] Y. Li et al., PRL (2002) - Phase
[8] Y. Li, submitted to PRL (2003) - Phase

CTR → SASE-FEL

[2] A.H. Lumpkin et al., PRL (2001) - " Observation"
[5] A.H. Lumpkin et al., PRL (2002) - Sidebands, Spectrum
[6] A. Tremain et al., PRE (2002) - Bunching factors

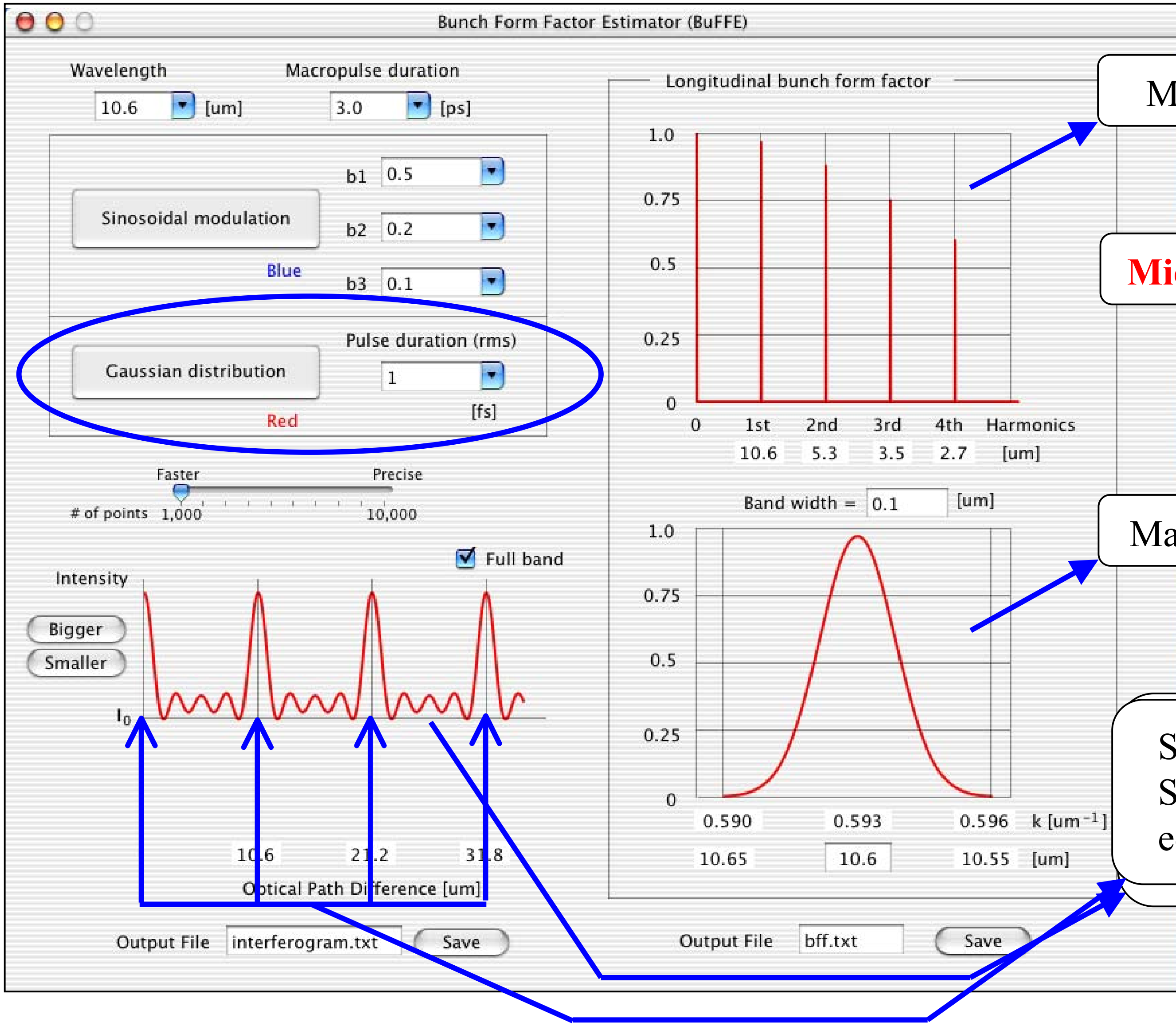
IFEL

[1] Y. Liu et al., PRL (1998) - " Observation "
STELLA → [3] W. Kimura et al., PRST. (2001)

*UR : Undulator Radiation

[#] : order of publication

Interferogram and spectrum of CTR from 1 fs microbunches



Microbunch duration

Microbunch distribution

Difficult

Macropulse distribution

Shot noise

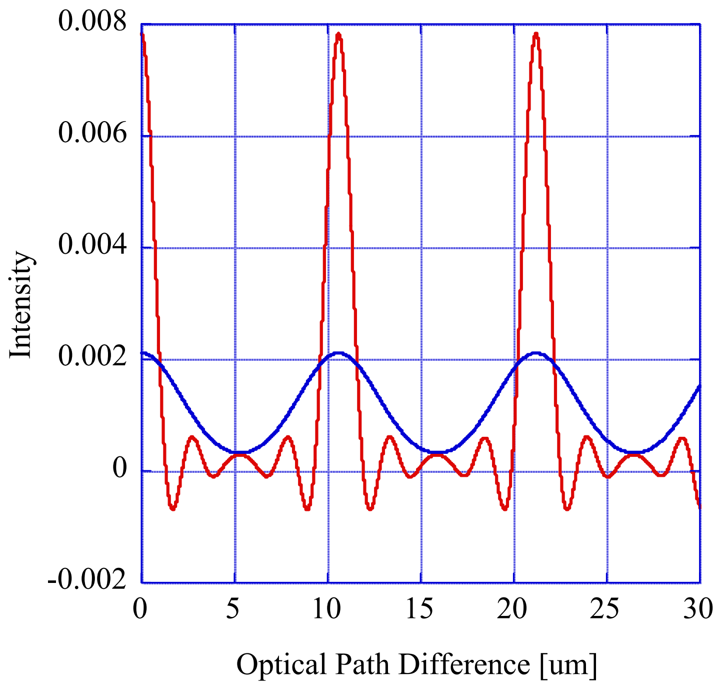
Spacings and shapes : Same among center and edges?

Interferogram and spectrum of CTR

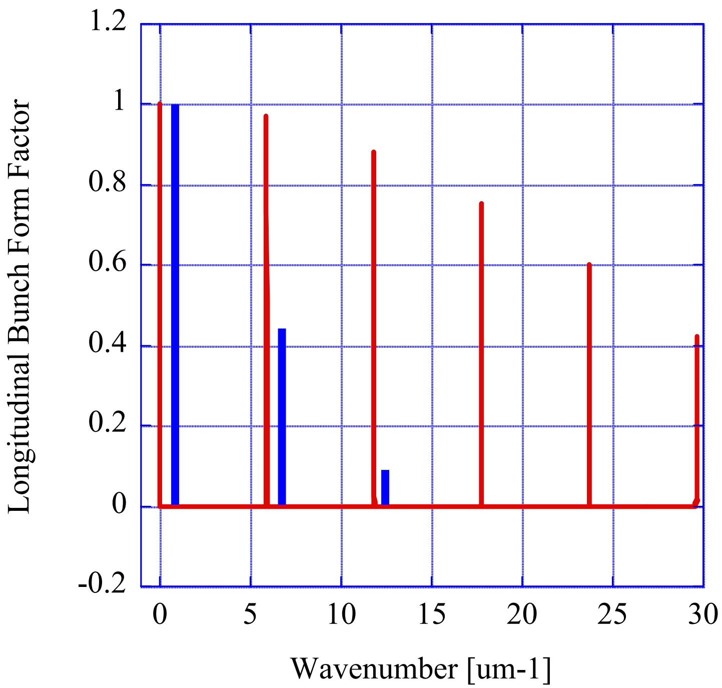
Red : 1 fs **Blue : 5 fs**

Assumption : full band, same charge, Gaussian distribution

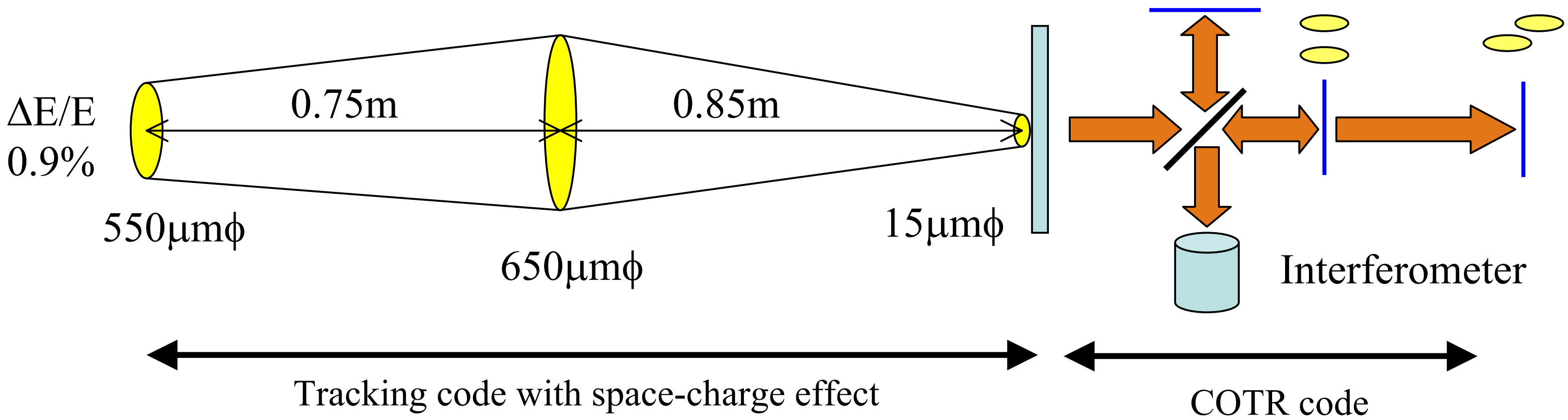
Interferogram



Longitudinal bunch form factor



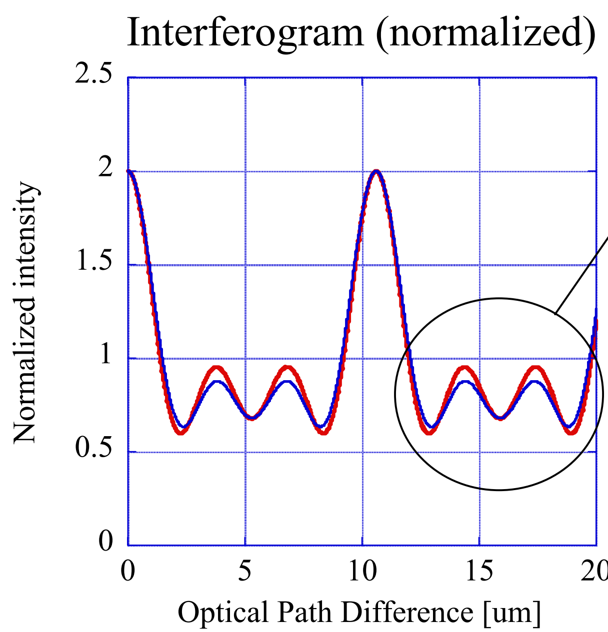
Interferogram of CTR



Pulse edge
0.2 pC/microbunch
1.0 fs

Pulse center
2.0 pC/microbunch
1.5 fs

1st, 2nd and 3rd harmonics are interfered.



Visibility
1.0 fs -> 4.4
1.5 fs -> 6.2

Effects of
- space charge
- energy modulation via IFEL
- difference of spacing

Expected results and difficulties

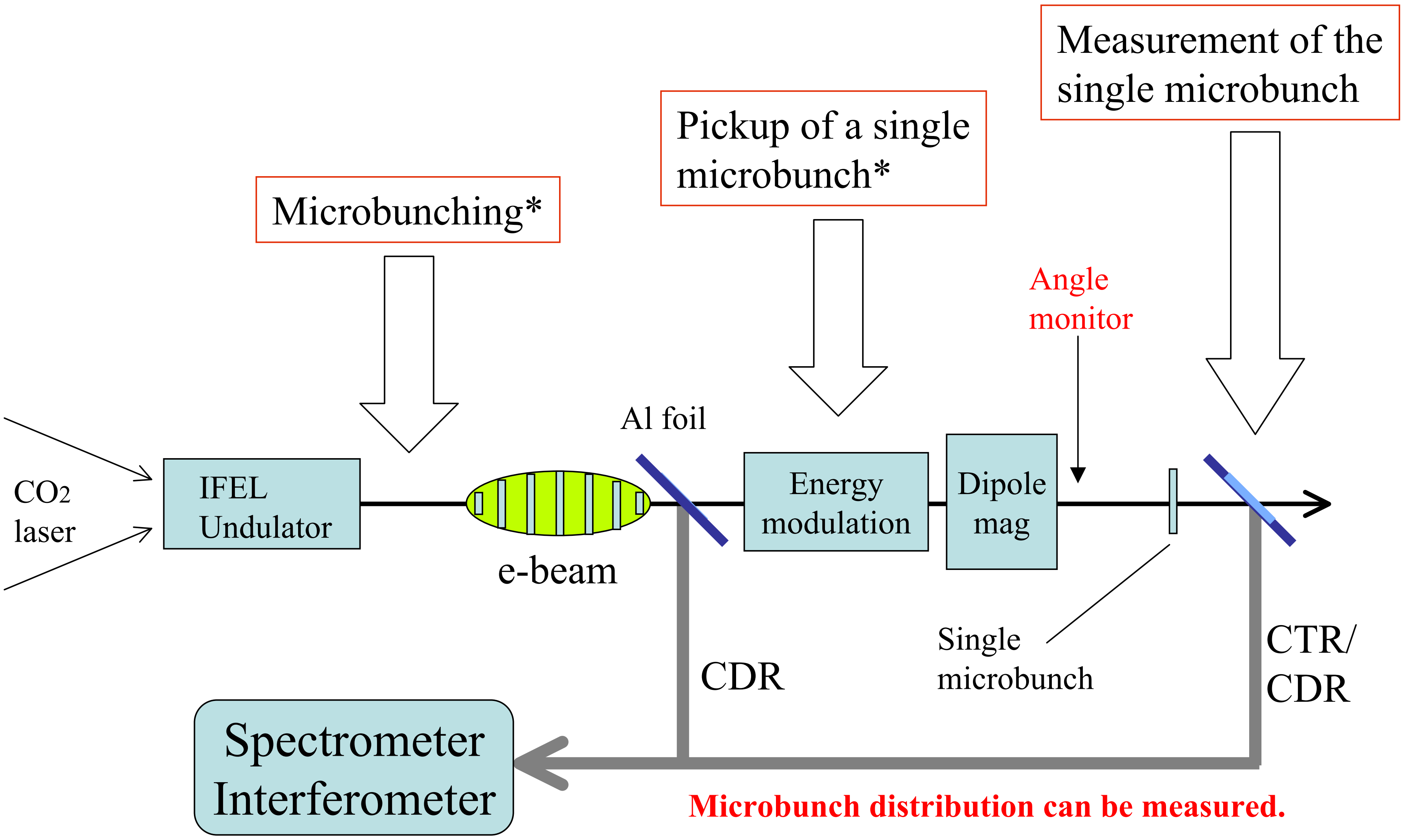
SASE-FEL	Bunching factors
IFEL	Macro/micro-pulse durations/distributions

- Macropulse distribution (cf. Effect of CSR)
- Microbunch duration (cf. Effect of space charge)
- Difference between macropulse center and edges
- Shot-noise of CTR

could be measured.

** It is difficult to see microbunch distribution for microbunch train.

Microbunching and measurement



Microbunch distribution can be measured.

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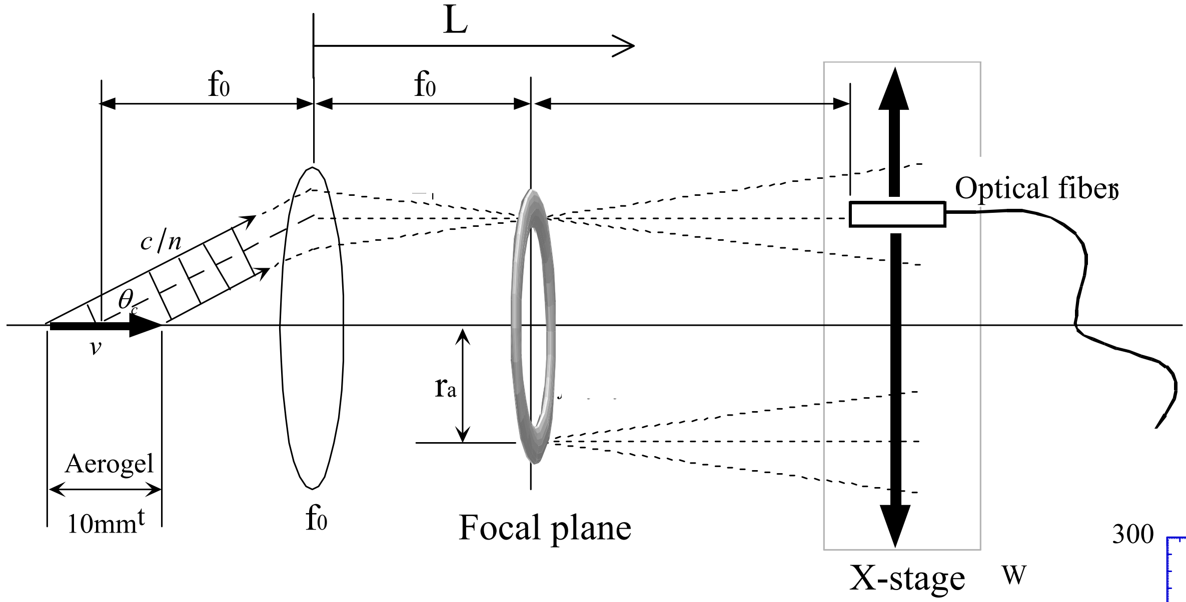
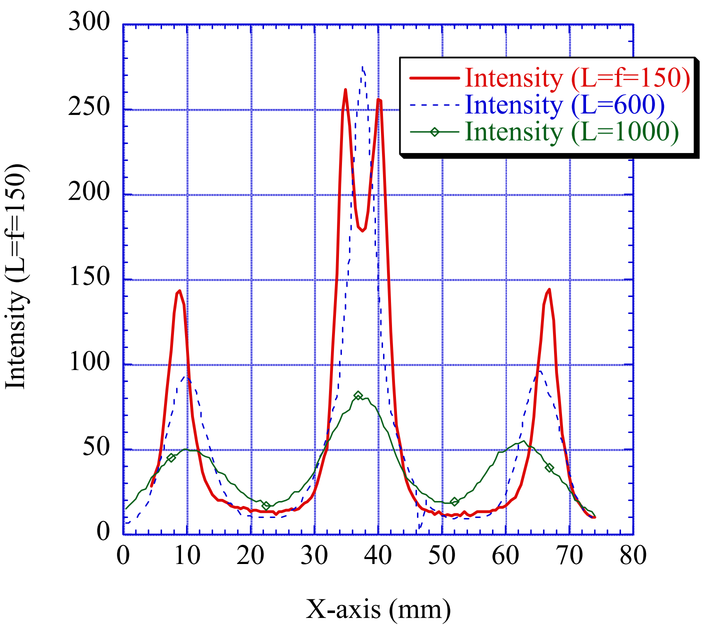
Observation of Cherenkov radiation @ UT, Japan



35MeV, 200pC, 3mmϕ, in air

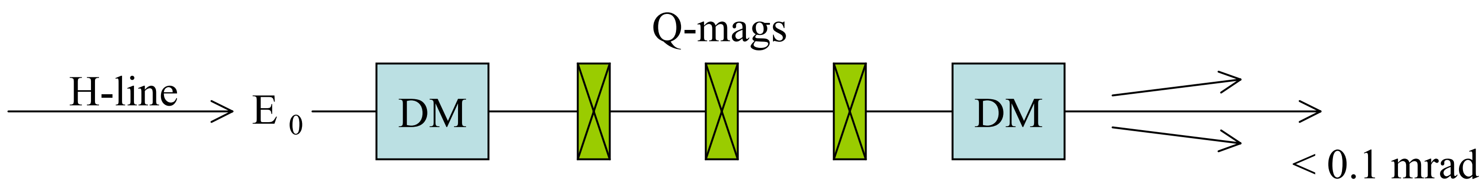
Experimental result @ UT



Spherical aberration
Off focus
Poor resolution due to 2 mm diameter
of optical fiber bundle

Beam angle monitor - applications -

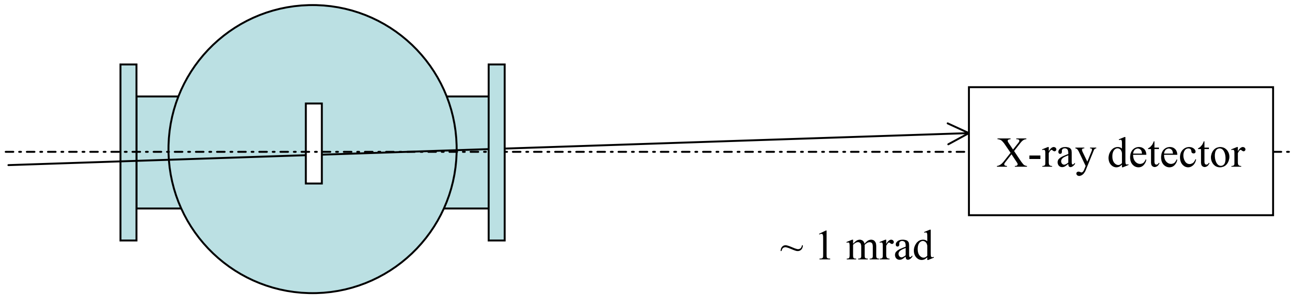
Observation of dispersion



E_0 [MeV]	D_x [mm]	D_{px} [rad]	$D_x\Delta p/p$ [mm]	$D_{px}\Delta p/p$ [mrad]
59.4	-49	-9	0.5	0.09
60.0	11	4	0.1	0.04
60.6	71	18	0.7	0.18

* $\Delta p/p = 1$ %

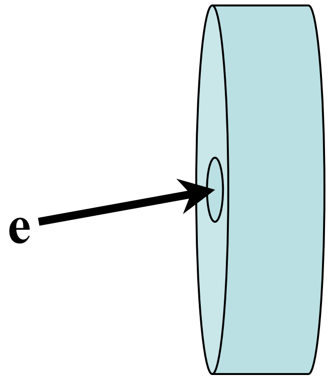
Compton scattering experiment



Beam angle monitor - questions -

How about non-destructive measurement?

Thin radiator with small hole might be useful.



The main beam could emit Cherenkov radiation.

Halo beam can emit Cherenkov radiation.

Interferogram and spectrum of COTR   3fs microbunch