Undulator Alignment for the SPring-8 XFEL

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世 界 地 図
E-XFEL
HERA
The LCLS
(Linac Coherent Light Source)
LCLS
SPring-8
ア ジ ア
ロ シ ア
中 国
日本
オーストラリア
アメリカ合衆国
インド洋
太 平 洋


bin
札幌市
仙台市
さいたま市
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SPring-8 site
SPring-8 (1436 m)
since 1997
XFEL (700 m)
from ~2011
CG

Japan's XFEL: SPring-8 Compact SASE Source (SCSS) Concept

Use of short-period undulator

↓

Suppression of acceleration energy

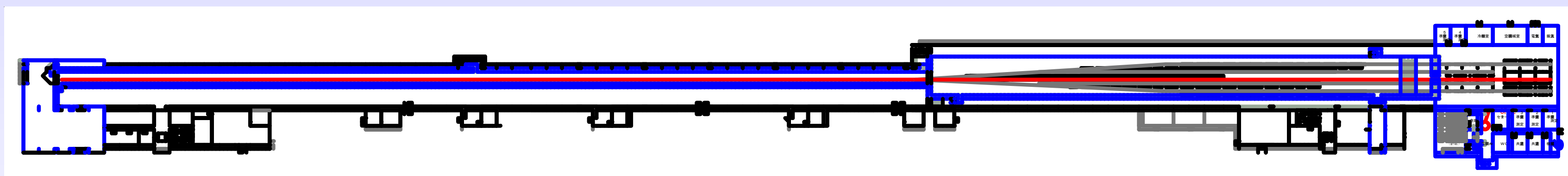
+

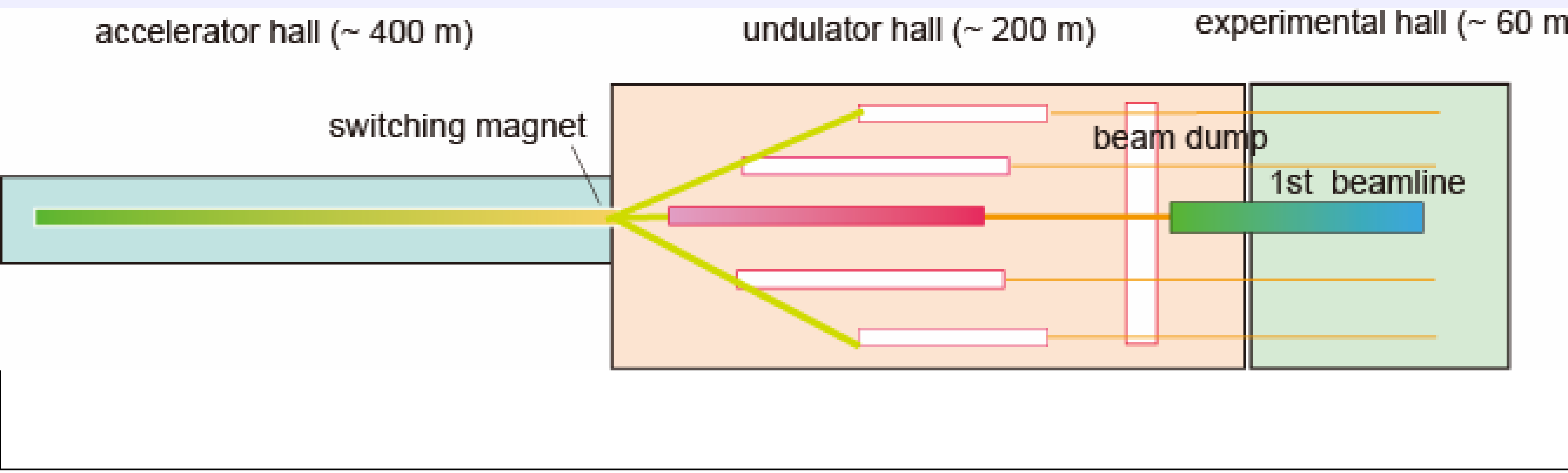
Use of high-gradient linac

$$\lambda_{photon} = \frac{\lambda_{magnet}}{2\gamma^2}\left(1+\frac{K^2}{2}\right)$$

=

Total length of 700 m

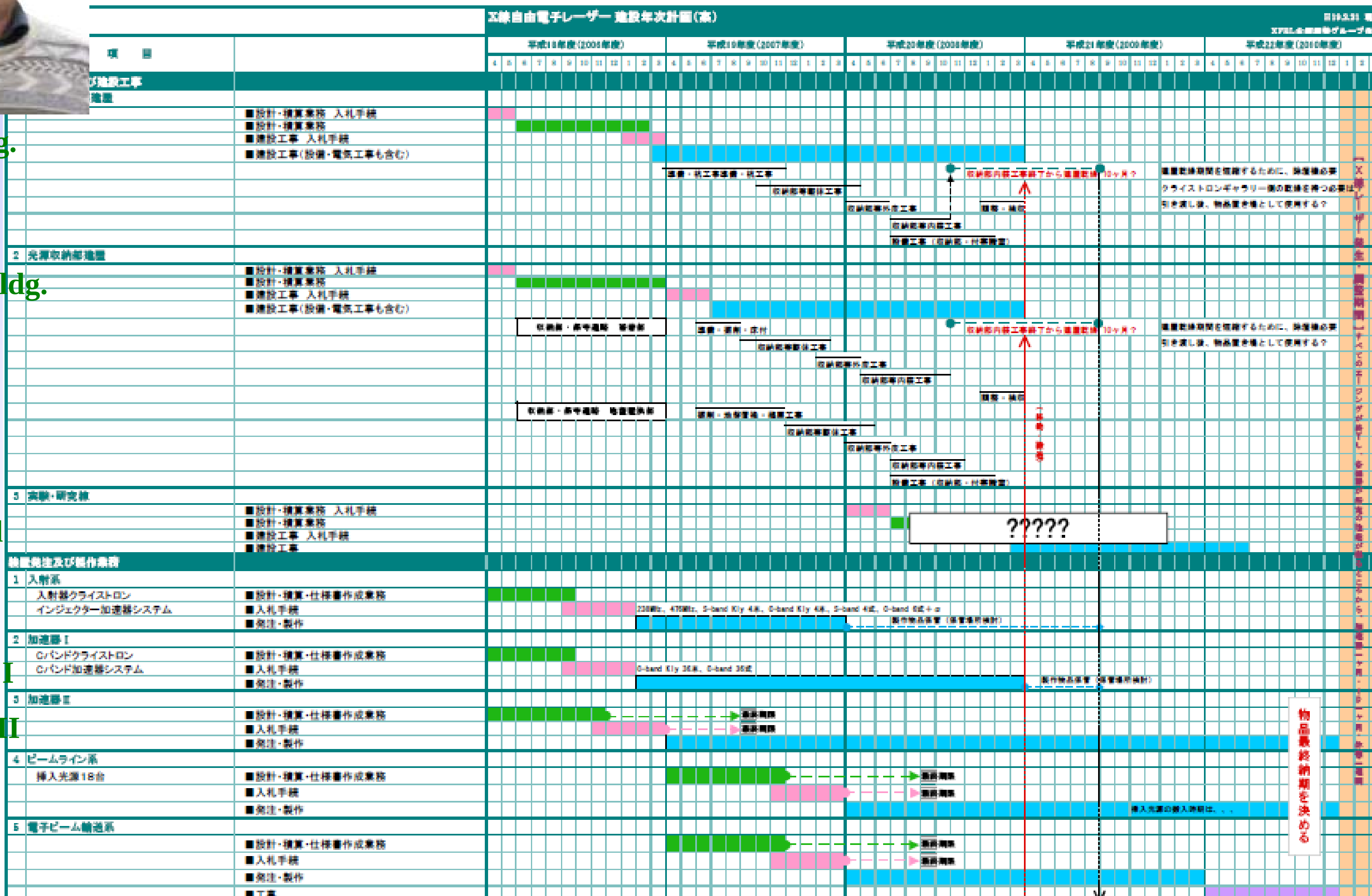




Project Schedule

Dr. Kumagai

FY2006 2007 2008 2009 2010



Linac Bldg.

Undulator Bldg.

Exp. Hall

Injector

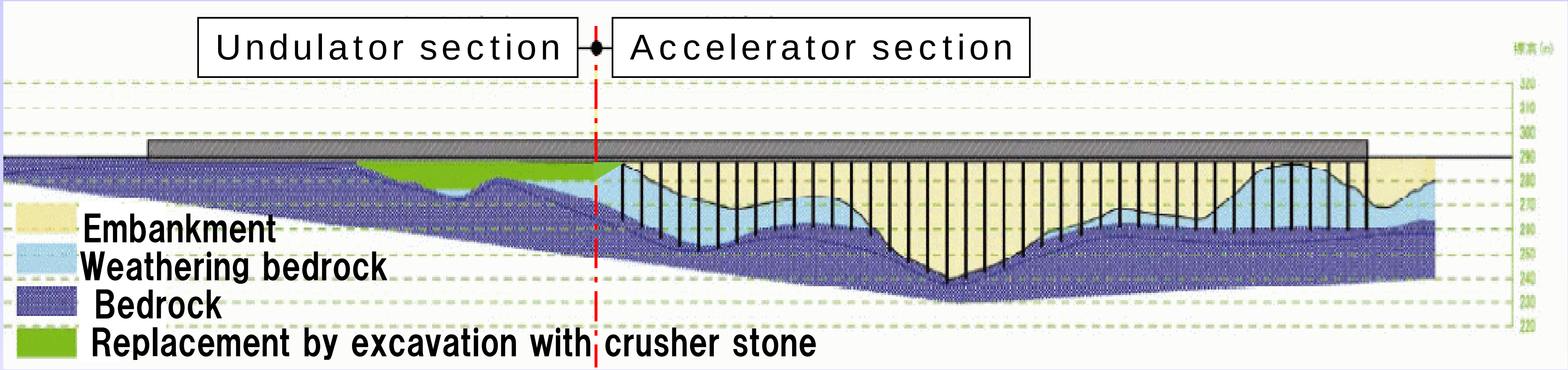
Accelerator I

Accelerator II

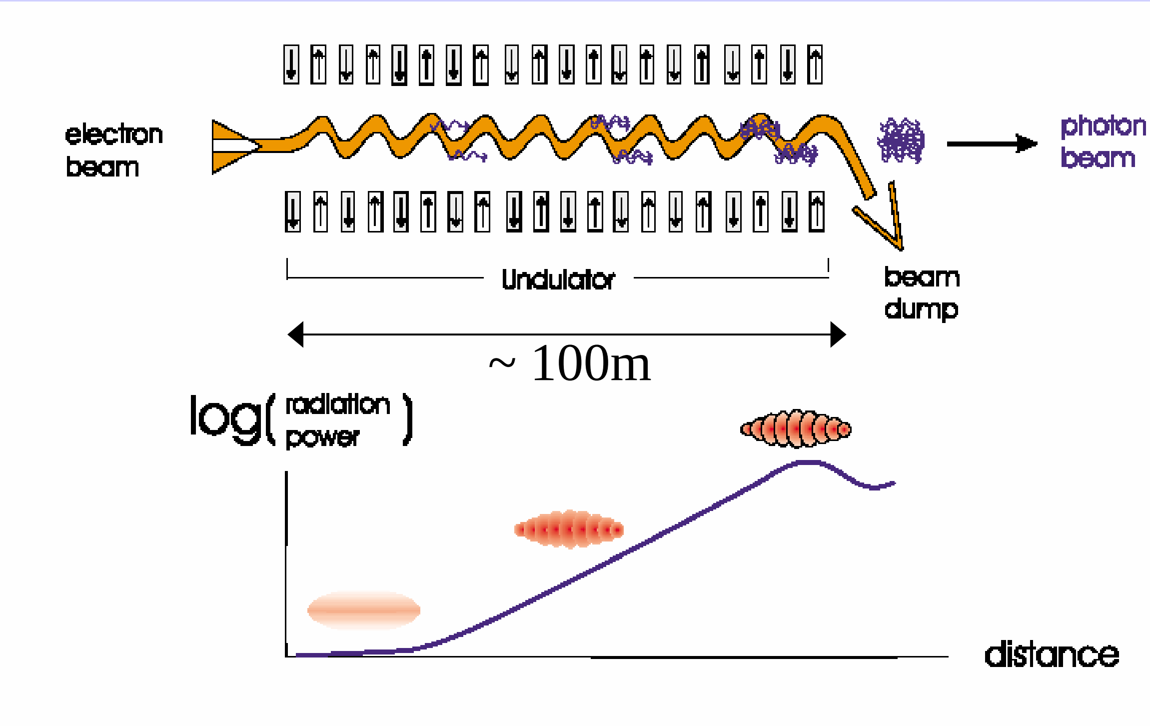
Beamlines

EBT

Undulator hall



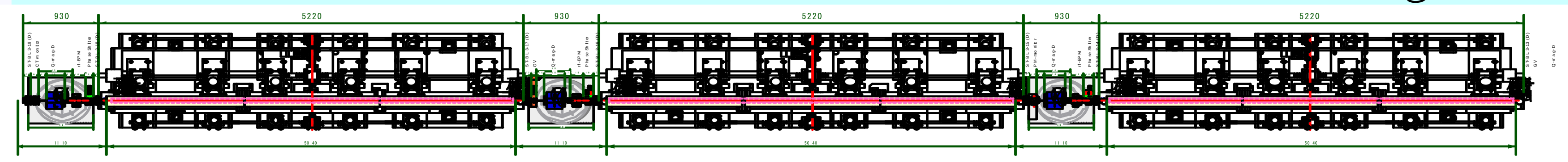
Undulator alignment



Dr. Kitamura

overlap of
e-beam & p-beam

5 m ×18 segments



Segmented undulators should work as if they were single module !!

T. Tanaka, SIMPLEX

Criteria

1. Straightness of trajectory: θ_C < 0.6 urad ($L\theta_C$ <3 um)
2. Magnetic field deviation: $\Delta K/K$ < 2e–4

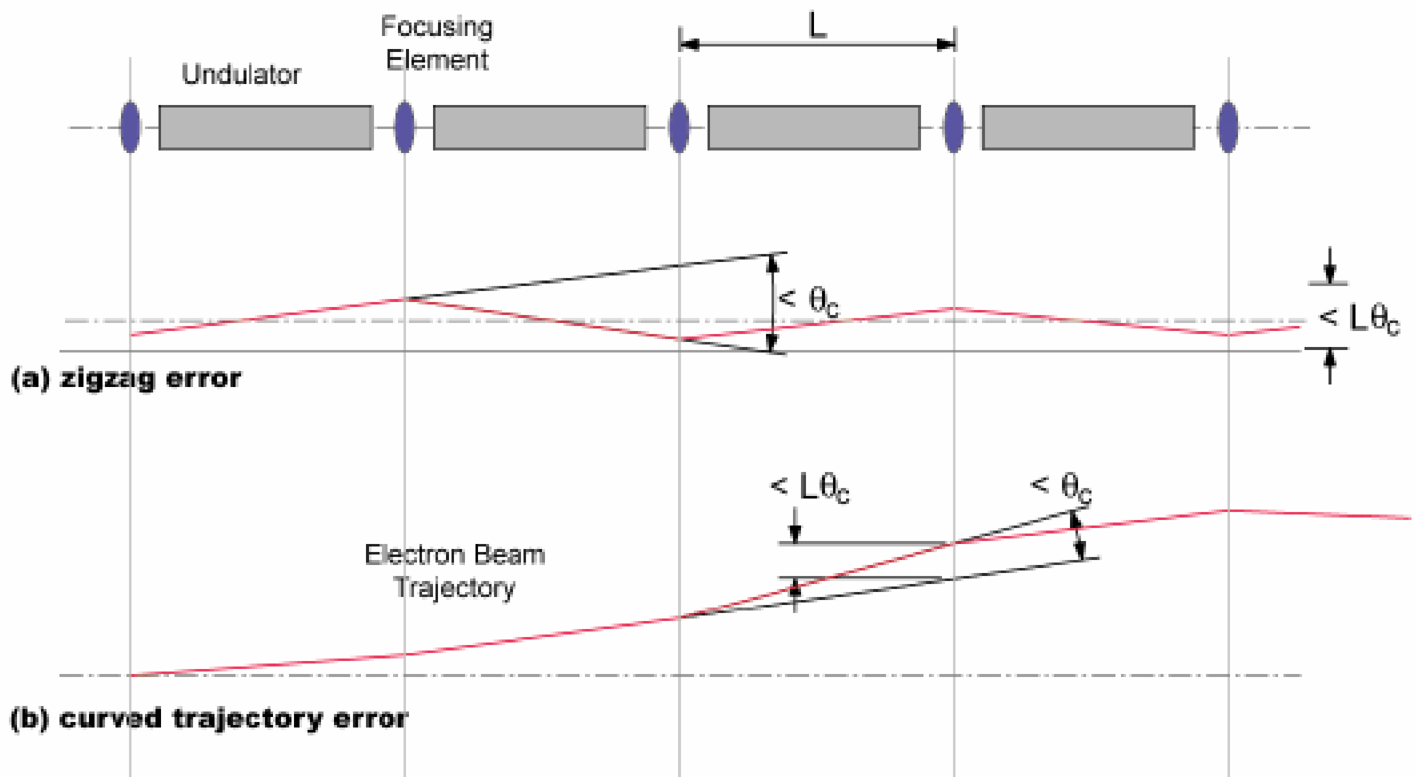


Fig. 1. Trajectory error model. (a) zigzag error, (b) curved trajectory error.

Different approaches

It is difficult to foresee the initial status (stability, reproducibility ...)
Multiple approaches should be prepared

E-beam:

Iris-coupled BPM (~ a few 10 um)

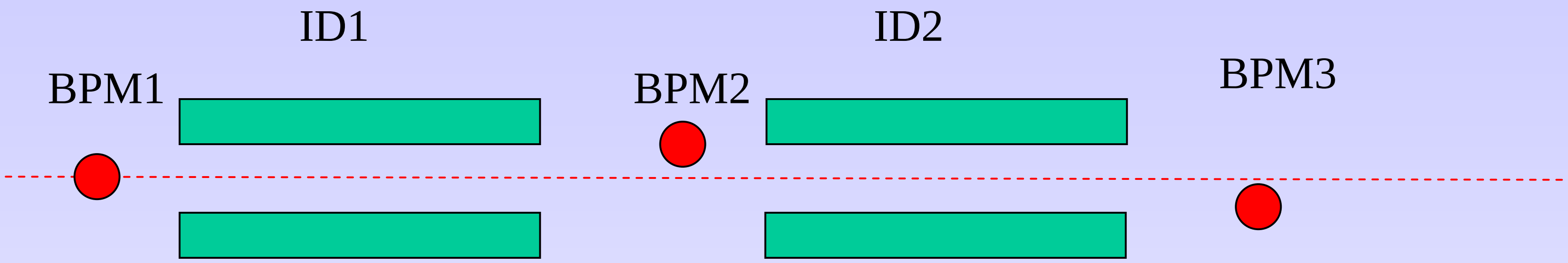
P-beam:

Spatial profile of monochromatic x-rays (~ a few um)

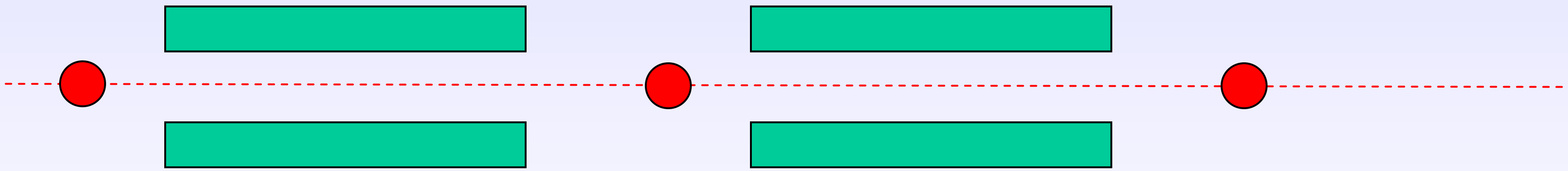
Spectrometer (Magnetic field deviation: 1e-4)

Alignment of BPMs

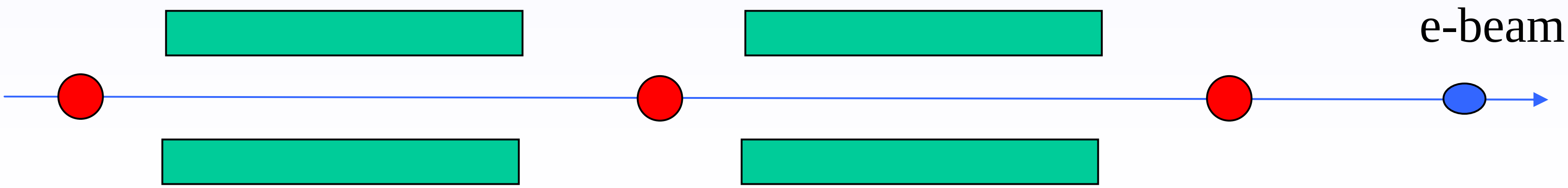
STEP 0: Initial condition



STEP 1: Align BPMs to straight line



STEP 2: Steer e-beam to the BPM origins



Iris-coupled BPM

Dr. Shintake

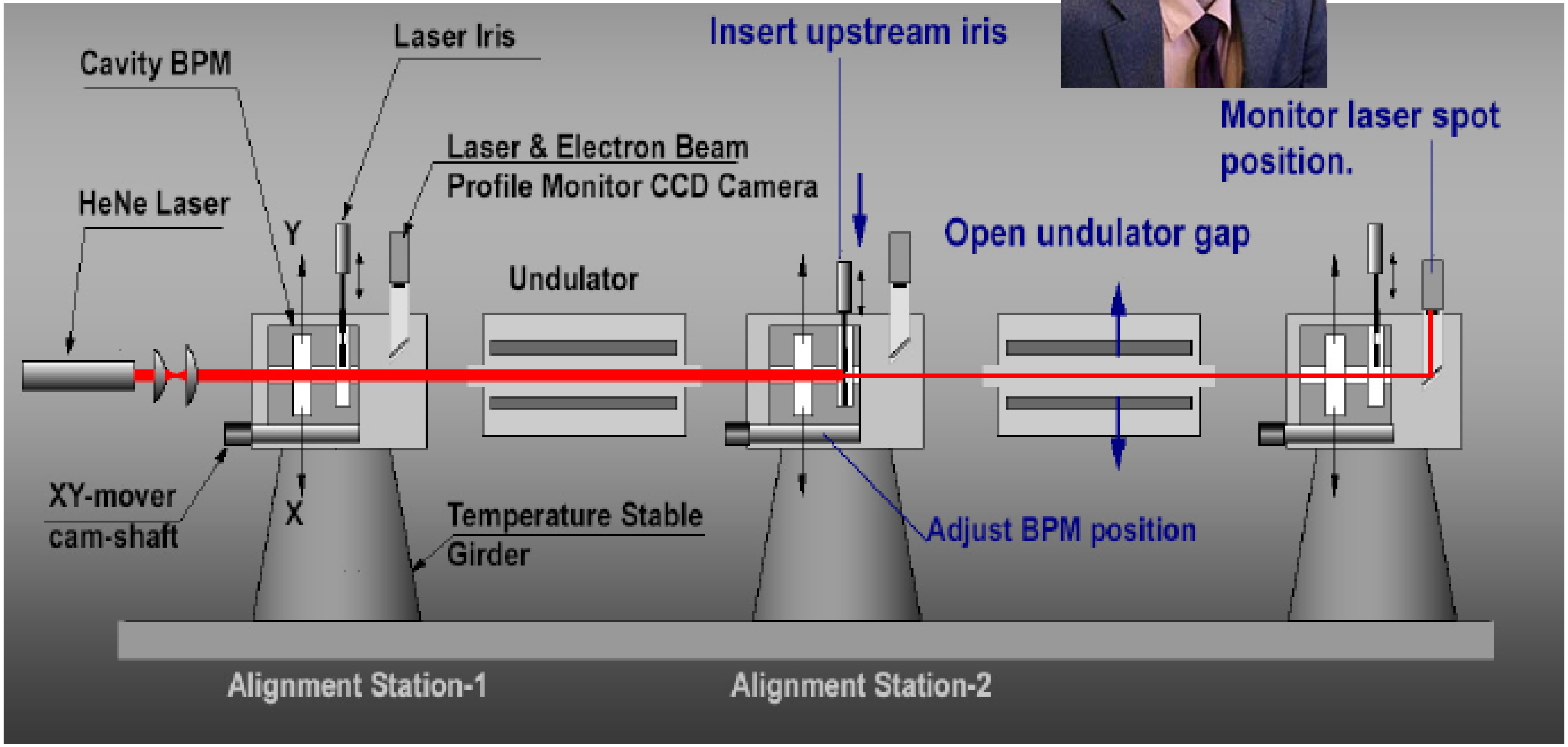


Fig. 2. Alignment stations in the undulator line are distributed in each 5 m separation. When we use HeNe laser alignment system, we open the undulator gap.

SCSS CDR 2005

Problem: Large diameter of laser iris (> 5 mm) is required for suppressing diffraction

→ Shorter wavelength radiation

Shorter wavelength source

1. UV: e.g., He-Cd laser

2. X-rays: Alignment undulator

Yang & Friedsam, IWAA 2006

PHYSICAL REVIEW SPECIAL TOPICS - ACCELERATORS AND BEAMS **9**, 030701 (2006)

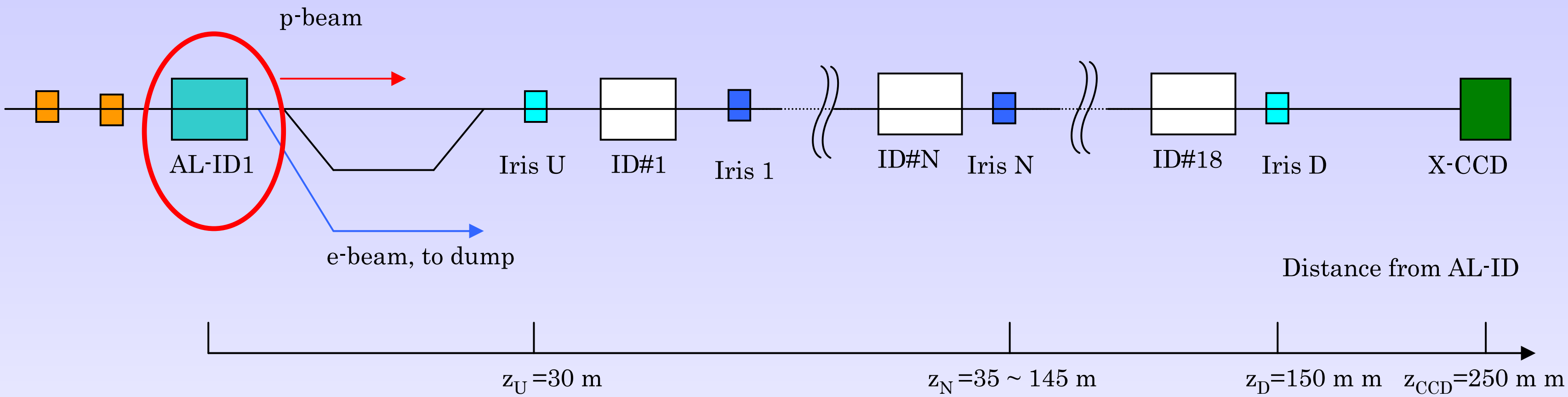
High-resolution accelerator alignment using x-ray optics

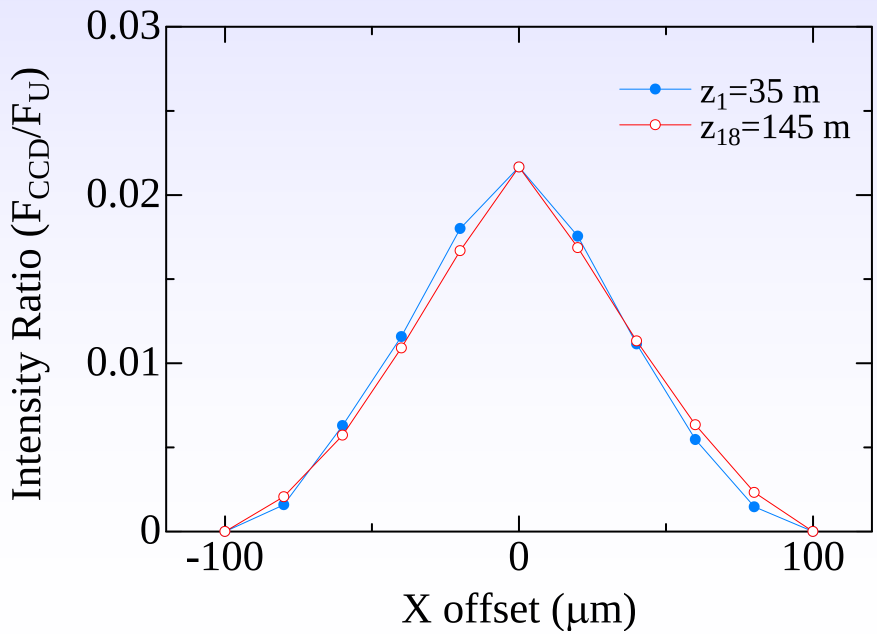
Bingxin Yang and Horst Friedsam

Advanced Photon Source, Argonne National Laboratory, Argonne, Illinois 60439, USA

(Received 21 December 2005; published 3 March 2006)

Alignment undulator



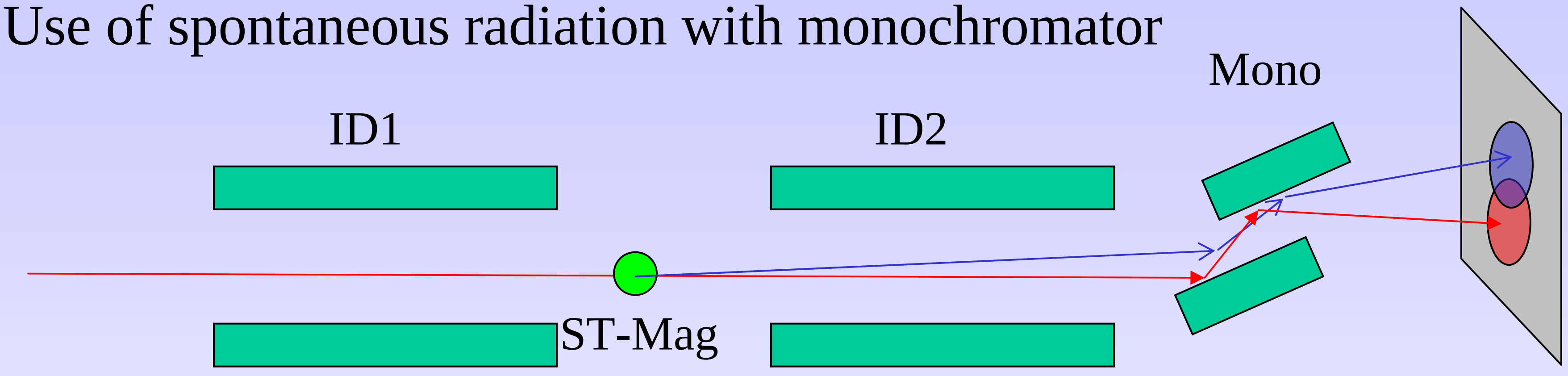


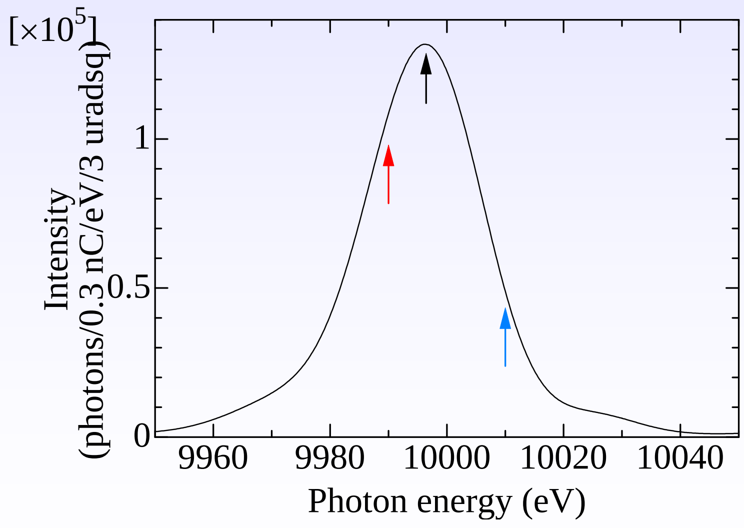
Iris diameter: 100 um

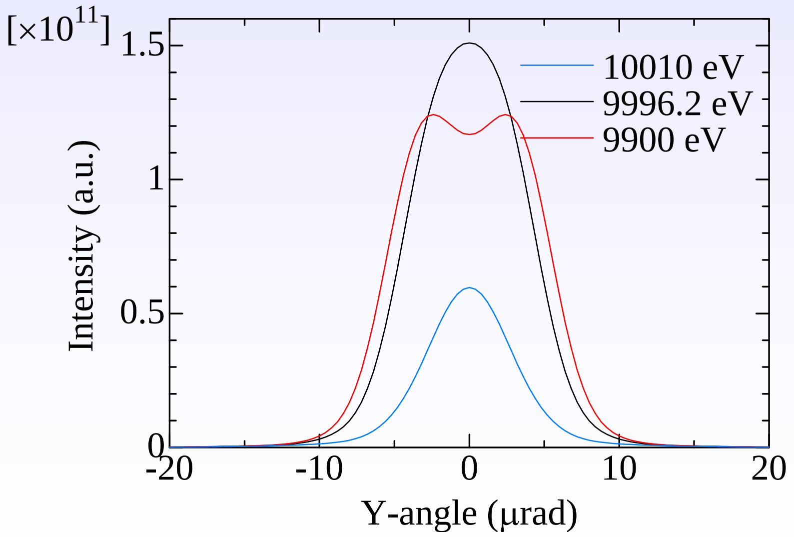
Sensitivity: ~ 10 um

P-beam based alignment

Use of spontaneous radiation with monochromator

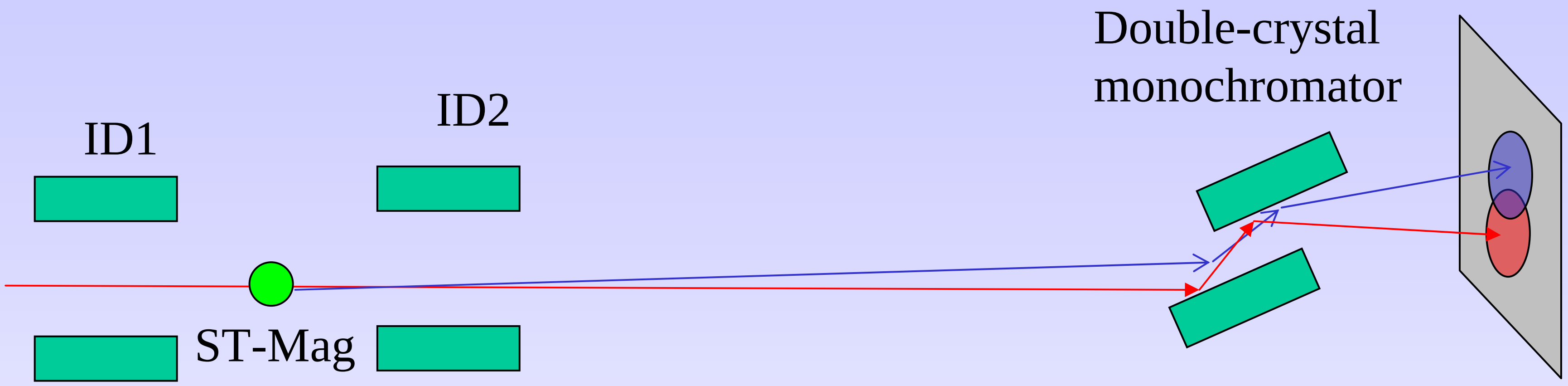


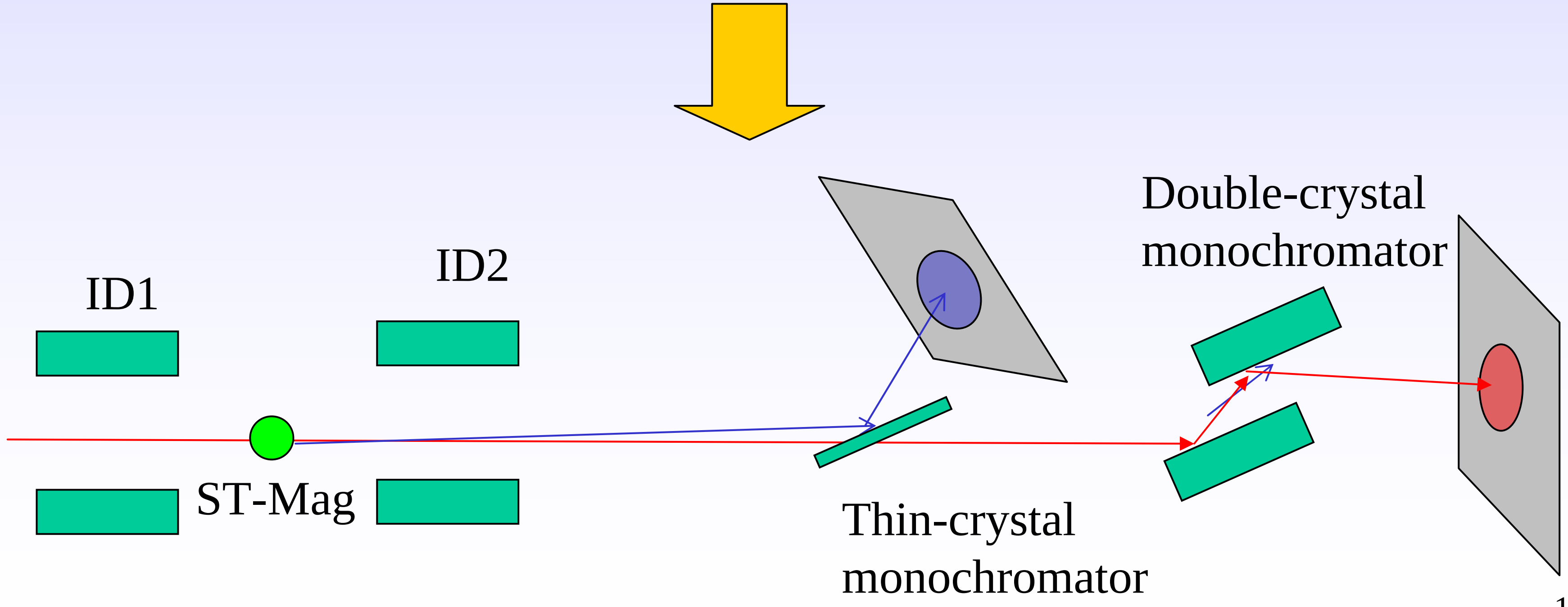




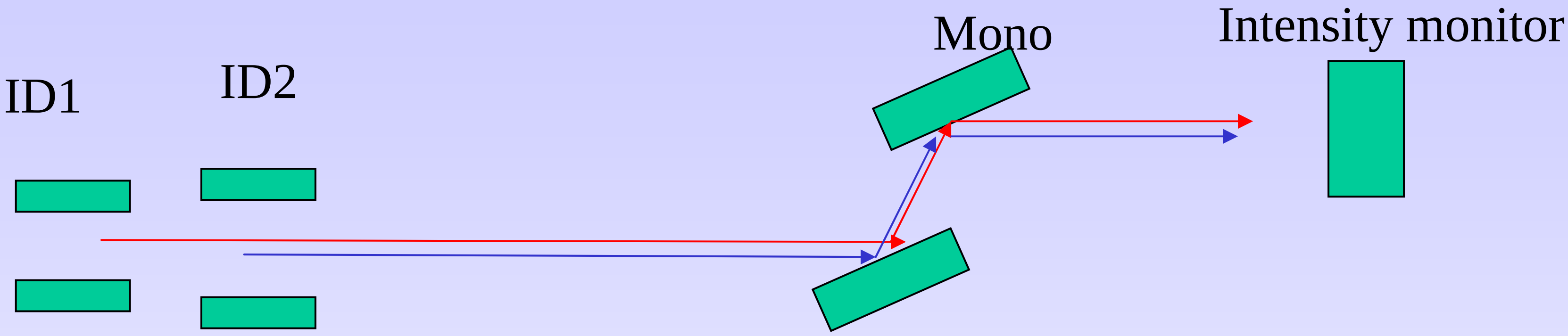
Requirement/FWHM = 0.6 urad / 8 urad = 8 %

Separation of profiles

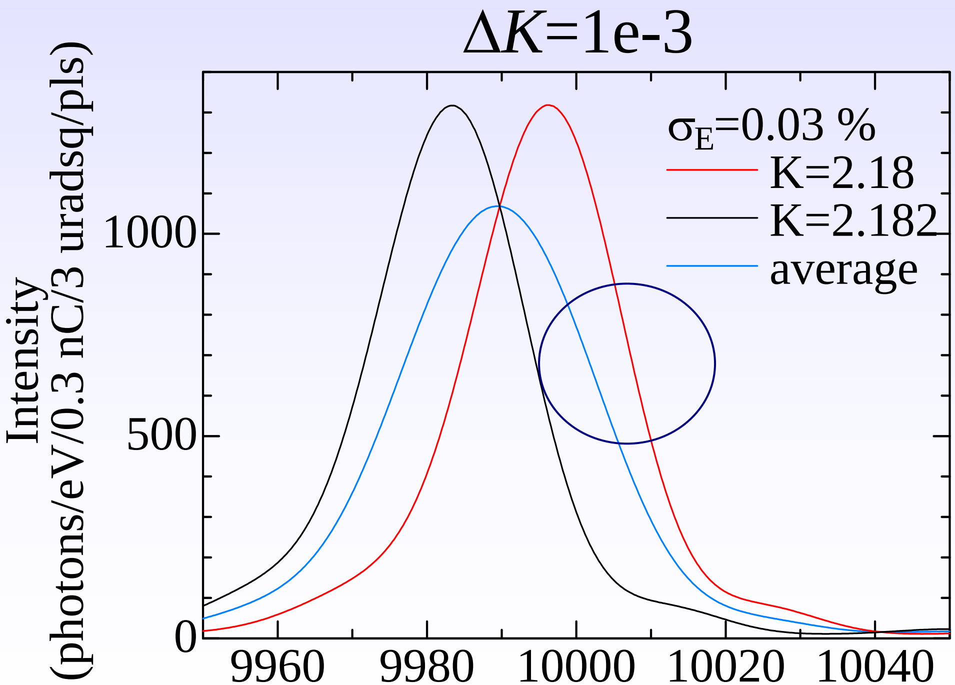




K-value adjustment (SLAC's proposal)



Scan of crystal monochromator



Shot-by-shot recording of :
E-beam energy, charge
P-beam energy, intensity

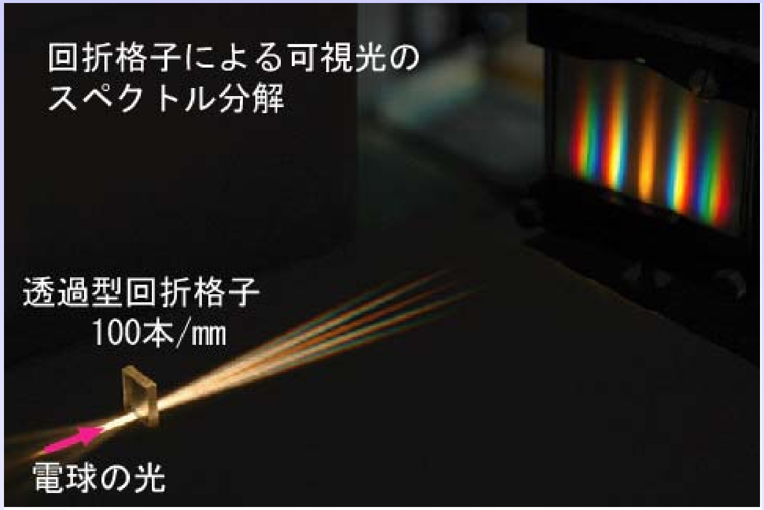
Problem: sensitive to e-beam jitter (charge, energy, position, angle) in the reconstruction process

Measurement of e-beam parameters (SLAC)

Charge meas res.	0.5%	!!!
Energy jitter	0.1% rms	
Energy meas. Res.	0.003% rms	!!!
E- angle jitter	0.5 μrad rms	
Detector noise	100 photons rms	
Peak signal	10^5 photons	

Single-shot spectrometer

Grating spectrometer:



Shigemasa & Yabashi, JSSRR, 2006

Low efficiency in hard x-ray regime:

⇨ Multilayer grating ?

Ishino, Koike et al, Appl. Opt. 2006

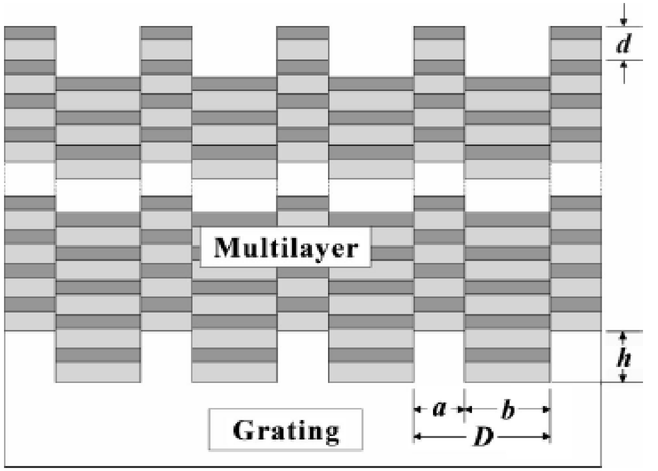
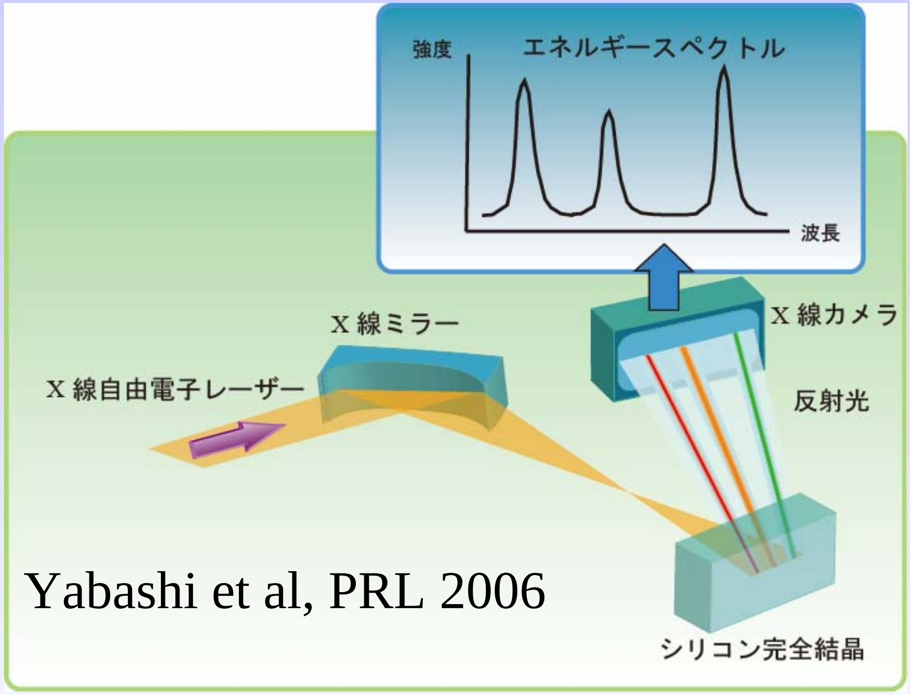


Fig. 2. Schematic diagram of a multilayer grating.

Single-shot spectrometer



Yabashi et al, PRL 2006

$$\Delta E / E = \Omega \cot \theta_B$$

Si111: $\Delta E = 1$ eV @ E=10 keV

($\Delta E / E = $1e-4)

Single-shot detection

Summary: Requirement for machine & undulator

	Trajectory alignment	*K*-value adjustment
Charge	~ 0.3 nC	As large as possible
Projected emittance	≤ 5 πmm.mrad ??	
Bunch compression	unnecessary	unnecessary
Energy spread σ_E (along bunch)	~ 1e-3	≤ 3e-4
Energy jitter (pulse-to-pulse)	~ 1e-3	~ 1e-3
Angular jitter (pulse-to-pulse)	< 10 μrad (1 mm / 100 m)	< < 3 μrad
Preliminary positioning accuracy of BPM	~ 50 μm	
BPM resolution & stability (single shot)	<< 4 μm	
e-beam kick inside undulator	<< 0.6 μrad ?? (Larger value may be tolerable)	

Summary

Trajectory:

Course tuning (~ 10 um): iris-coupled BPM,
alignment undulator

Fine tuning (~ um): Spontaneous radiation with monochromators, thin-crystal monochromator

Magnetic field:

Single-shot spectrometer

Imposes special condition for e-beam operation

2D-detector

High-efficiency, moderate rep. rate (~1 Hz),

resolution (~50 um)