Photon Optics at SCSS

Makina Yabashi and Tetsuya Ishikawa

SCSS/SPring-8/JASRI/RIKEN

fel 2006 @ Berlin, Sep 1st 2006

SCSS: Takao Asaka, Yoshihiro Asano, Hitoshi Baba, Teruhiko Bizen, Hiroyasu Ego, Toru Fukui, Shunji Goto, Hirohumi Hanaki, Toru Hara, Atsushi Higashiya, Toko Hirono, Naoyasu Hosoda, Takahiro Inagaki Shinobu Inoue, Miho Ishii, Yasuhide Ishizawa , Daisuke Iwaki, Koujiro Kase,Yoshitaka Kawashima , Hiroaki Kimura, Tomoyuki Kirimura , Masanobu Kitamura ,Satoru Kojima , Hirokazu Maesaka , Xavier Marechal, Sakuo Matsui, Hiroshi Matsumoto, Tomohiro Matsushita, Tetsuro Mochizuki, Jong-Seok Oh, Haruhiko Ohashi, Toru Ohata, Takashi Ohshima, Kazuyuki Onoe, Yuji Otake, Tatsuyuki Sakurai, Takamitsu Seike, Katsutoshi Shirasawa, Shinsuke Suzuki, Kazuhiko Tahara, Tetsuya Takagi, Sunao Takahashi, Takeo Takashima, Masao Takeuchi, Hitoshi Tanaka, Ryotaro Tanaka, Takashi Tanaka, Yoshihito Tanaka, Shingo Taniguchi, Takanori Tanikawa, Kazuaki Togawa, Rieko Tsuru, Shukui Wu, Makina Yabashi, Akihiro Yamashita, Kenichi Yanagida Chao Zhang ,

Noritaka Kumagai , Tetsuya Ishikawa, Hideo Kitamura , Tsumoru Shintake

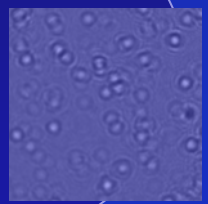
RIKEN/SPring-8, JASRI/SPring-8, KEK

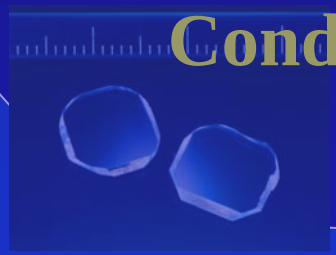
Diamond crystal: K. Tamasaku, Y. Shimizu, H. Sumiya (Sumitomo Electric Industry)
Beryllium window: S. Goto
X-ray Mirror: K. Yamauchi, H. Mimura, S. Matsuyama, H. Yumoto, ... (Osaka Univ.)
X-ray Spectrometer: J. Hastings, M. Zolotorev (LBNL) & Osaka people

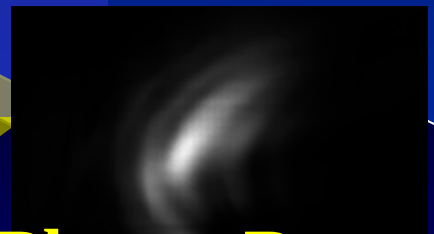
Photon Optics for XFEL

XFEL

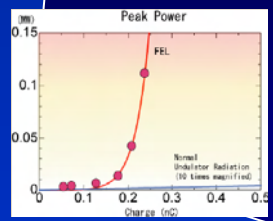
Photon Beam Conditioning

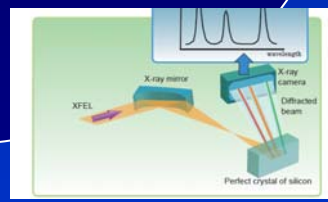




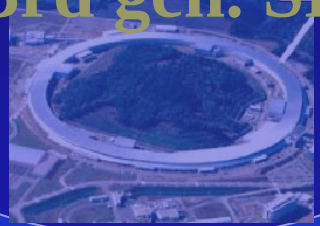


Photon Beam Diagnostics





3rd gen. SR

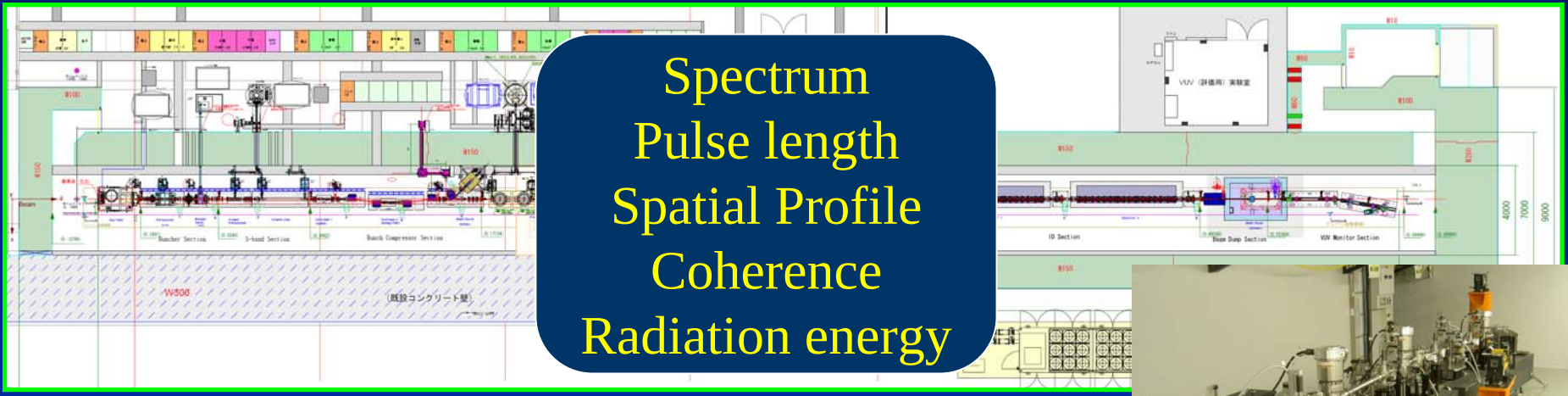


VUV FEL

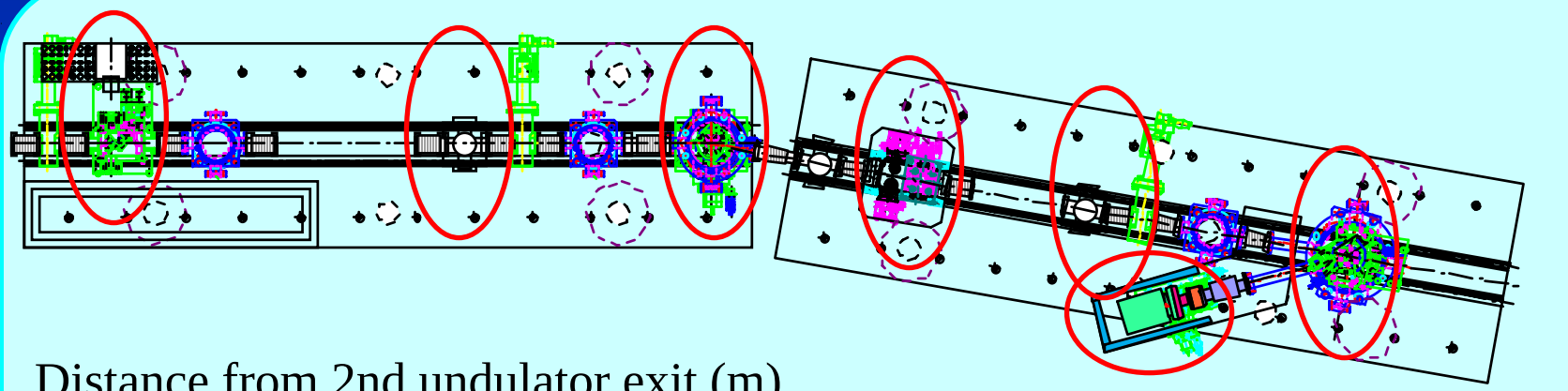
SCSS


Electron Source
Main Accelerator
Undulator
SASE-FEL
X-ray User
Low-Emittance
High-Gradient C-band
In-Vacuum Undulator
8 GeV SPring-8
SCSS-XFEL has been approved in January 2006
8 GeV, 0.8 A, SASE-FEL
Construction 2006-2010, at SPring-8
Beam commissioning ~2010
250 MeV
Test Accelerator

SCSS Prototype Accelerator



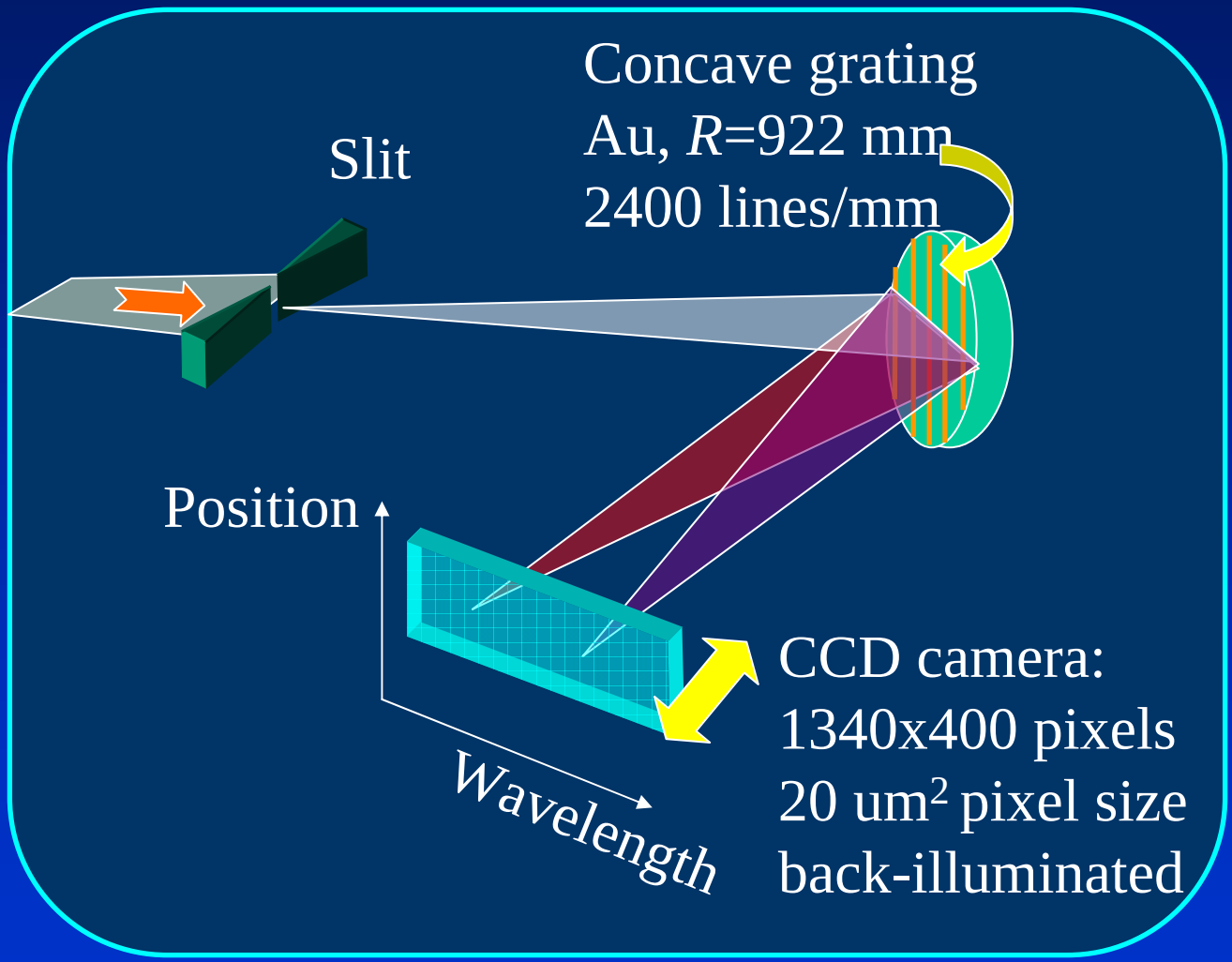
Spectrum
Pulse length
Spatial Profile
Coherence
Radiation energy



Distance from 2nd undulator exit (m)

5 6 7 8 9 10

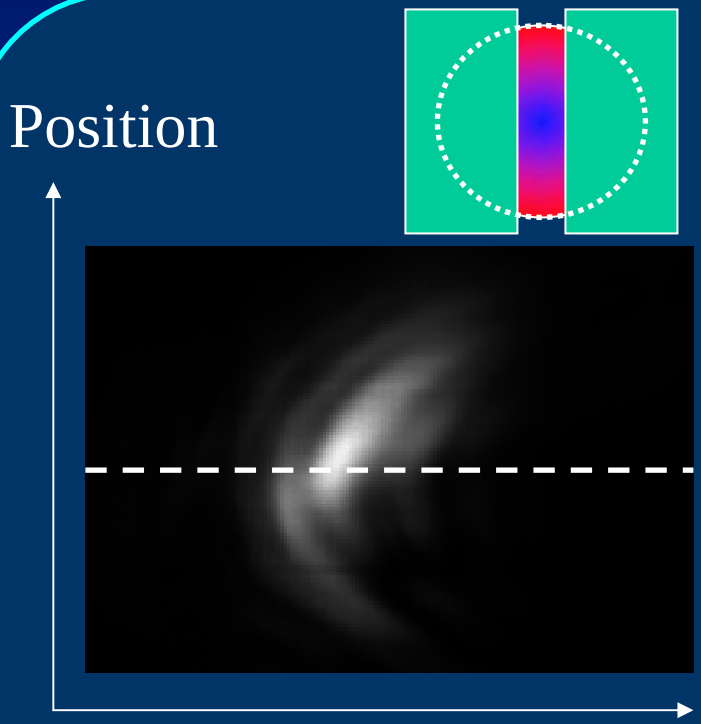
Spectrometer

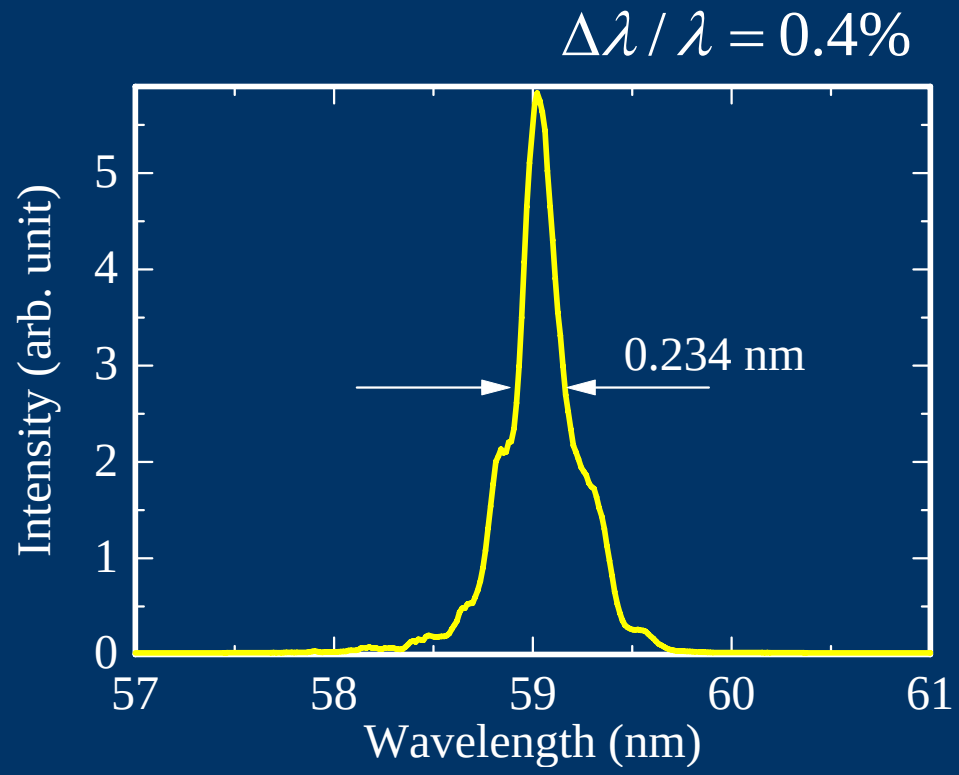


Normal incidence, constant deviation geometry

$\Delta\lambda/\lambda < 0.1\ \%@\ \lambda=58$ nm

SASE Spectrum



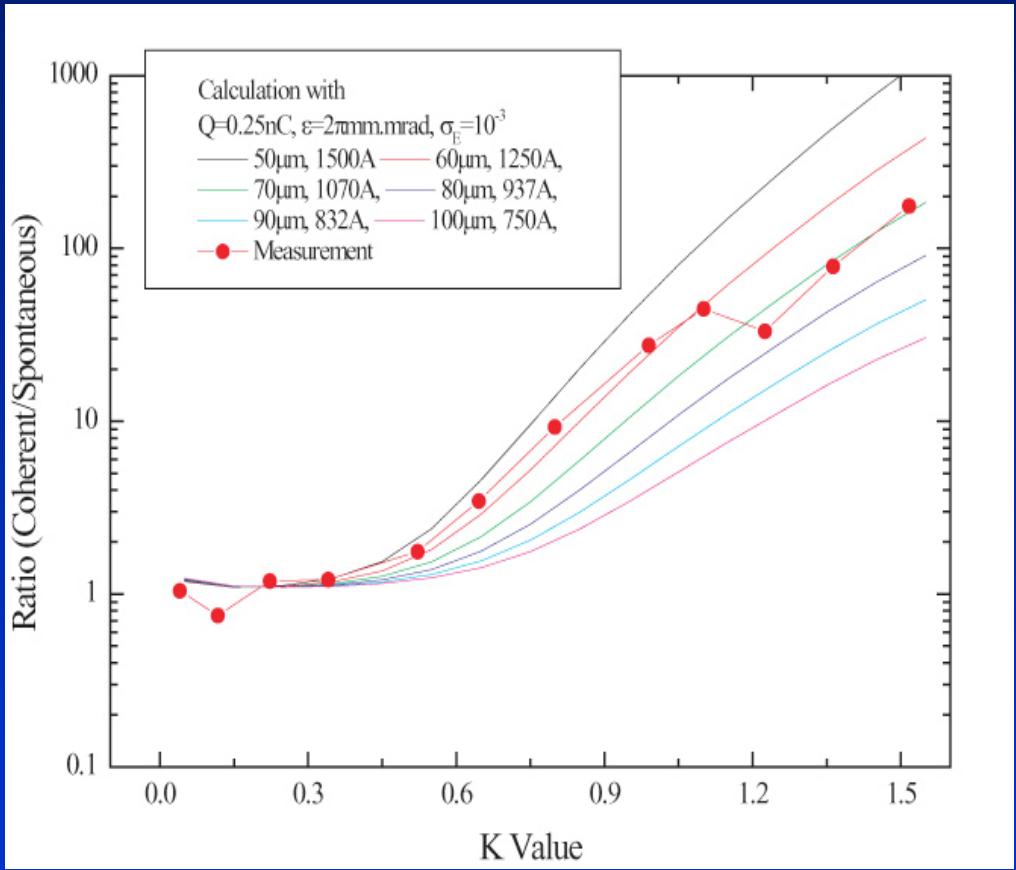


For rectangular pulse: $\Delta E\ \Delta t = 3.6$ eV.fs ➡ $\Delta t \sim 43$ fs

E-beam parameter

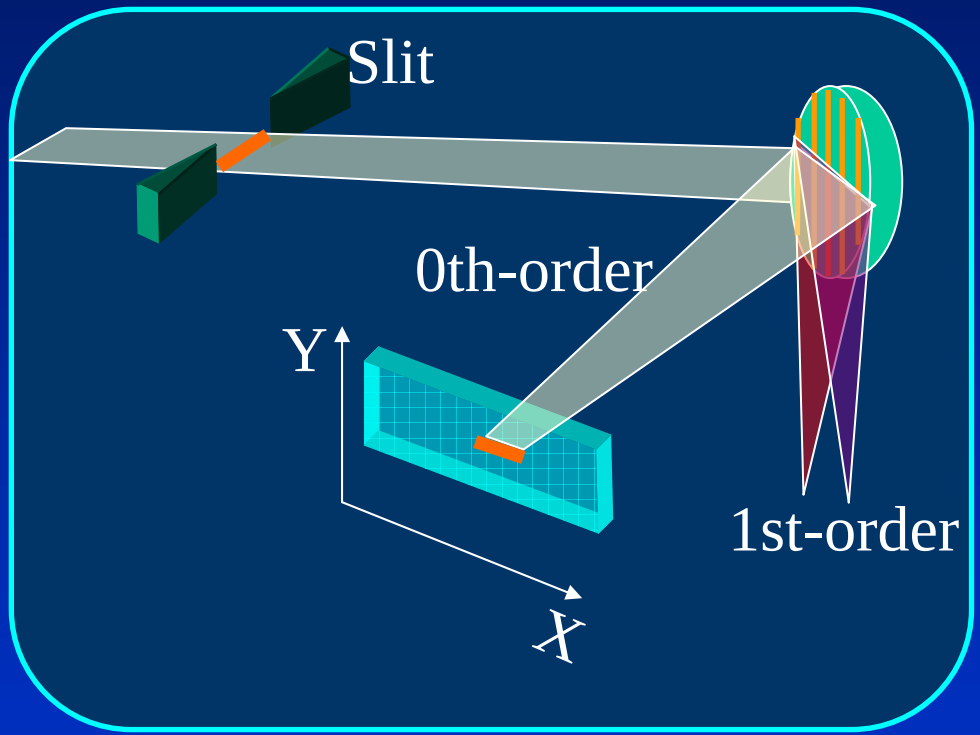
Angular photon flux v.s. K-value with ID#1

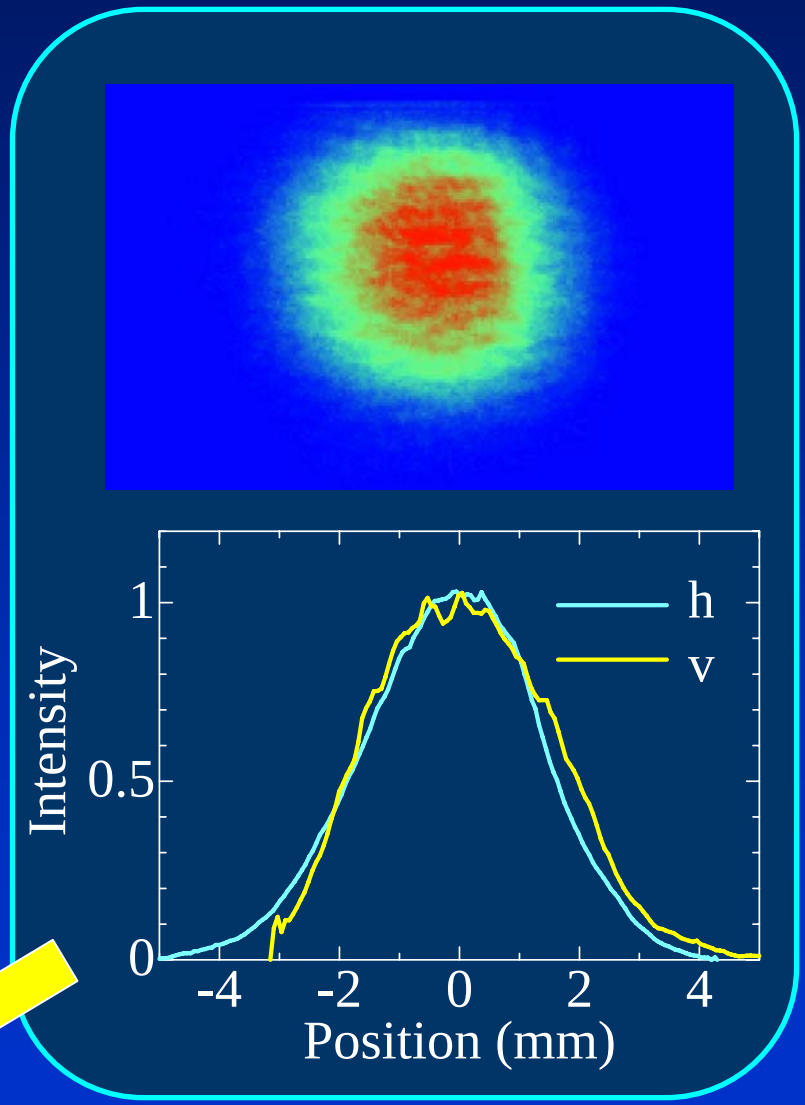
T. Takashi et al.



2π mm.mrad / 1.25 kA by 3DFEL simulator SIMPLEX

Spatial Profile

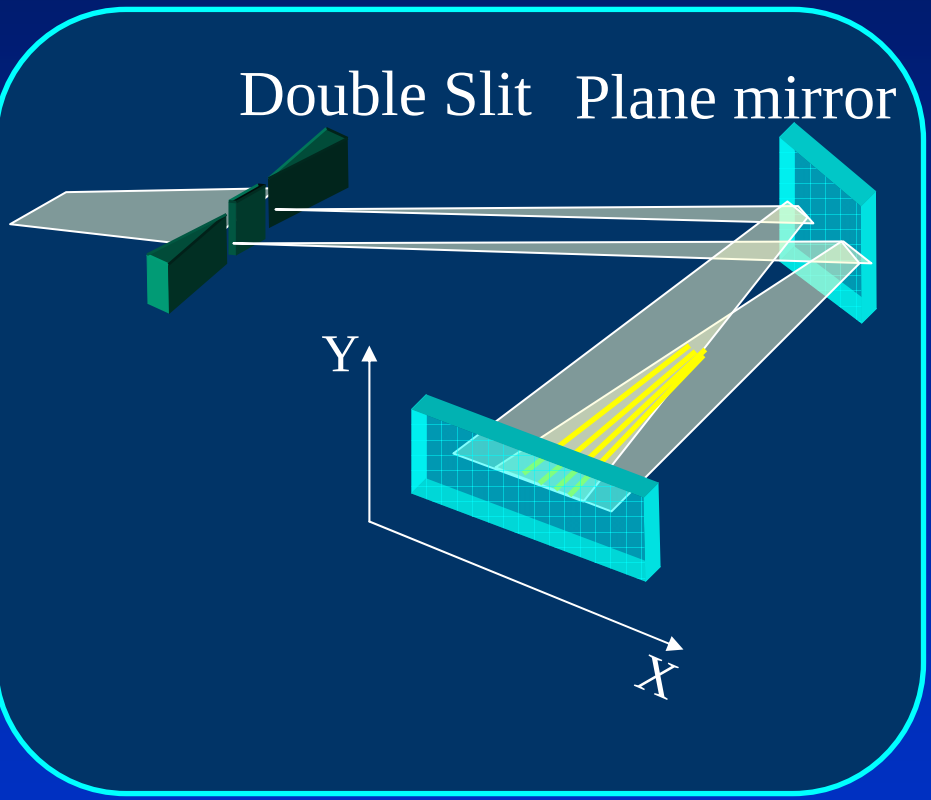


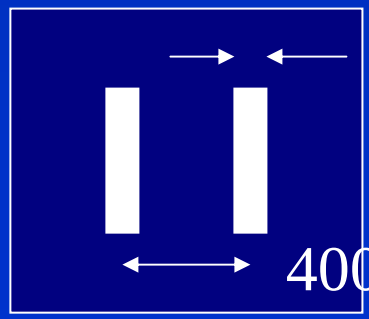


Beam size = 3.4 / 3.9 mm

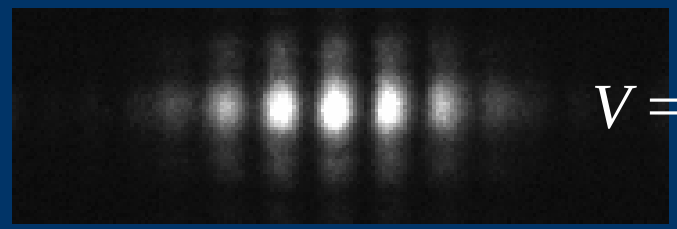
Divergence = 240 / 280 urad

Coherence

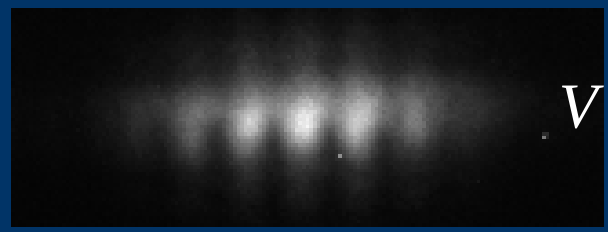


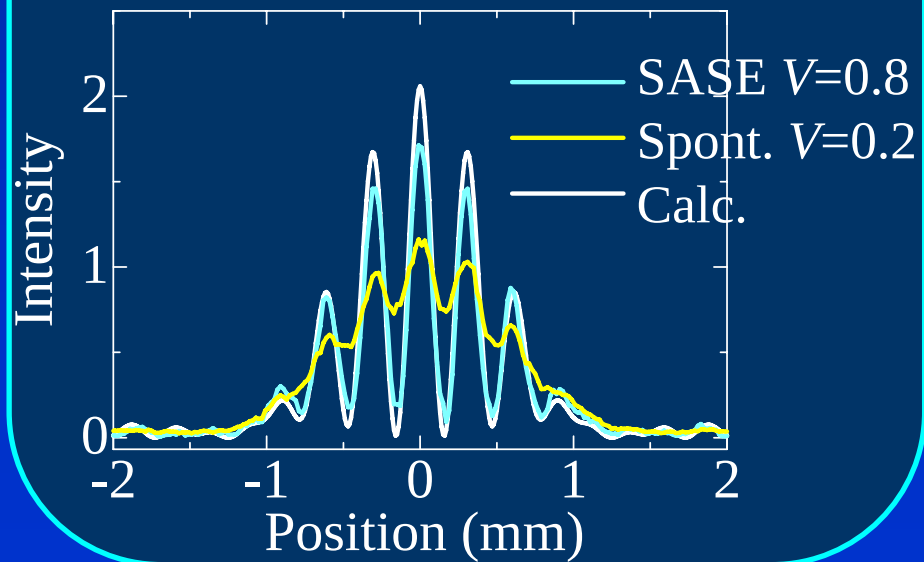


SASE, single shot

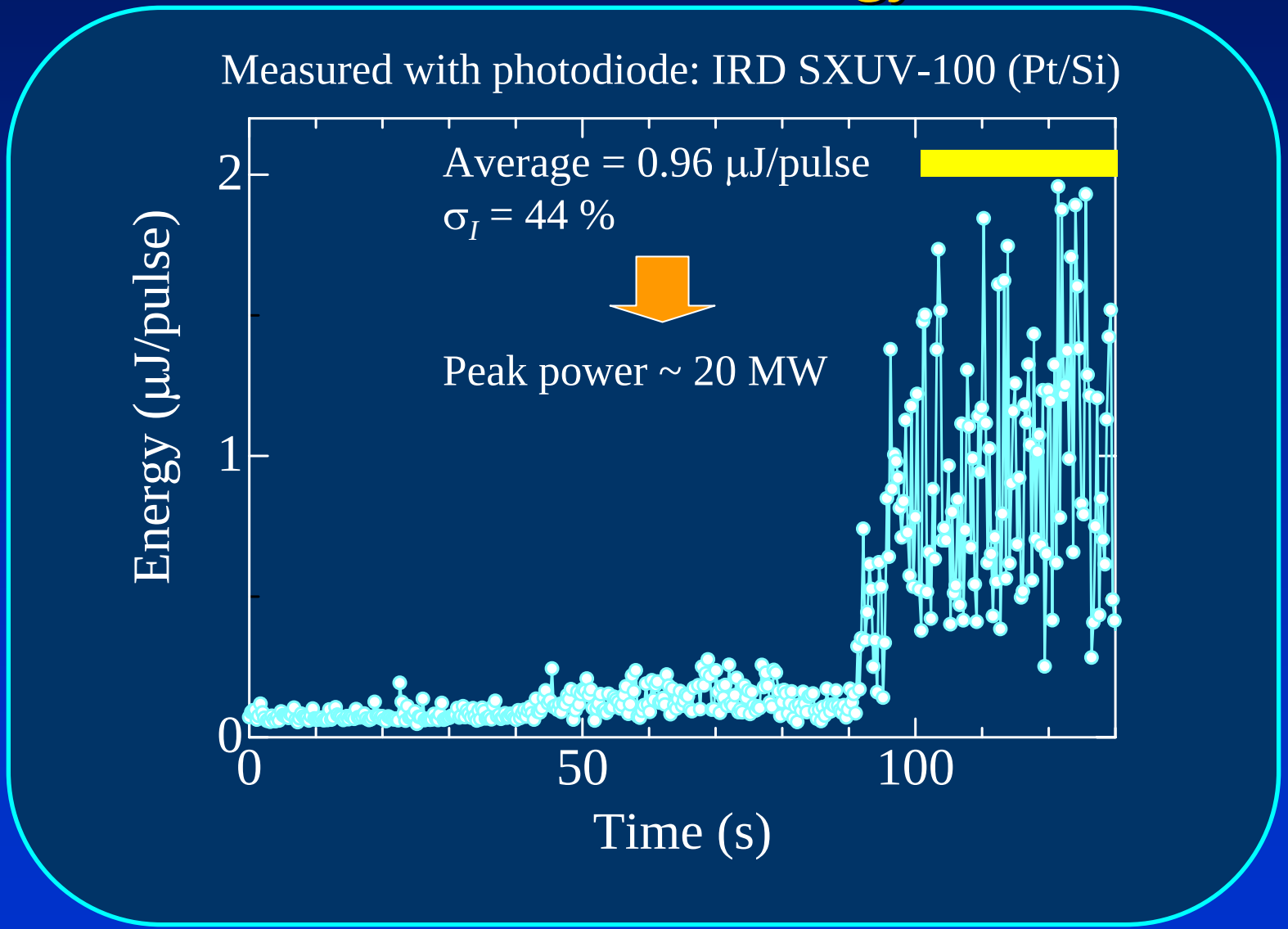


Spontaneous, 100 shots





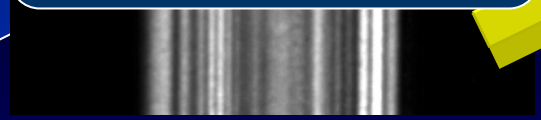
Radiation Energy



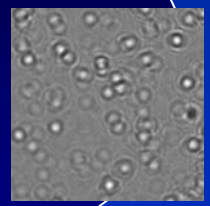
Photon Optics for XFEL

XFEL

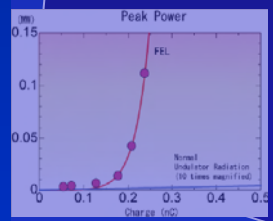
Dose
Spatial coherence

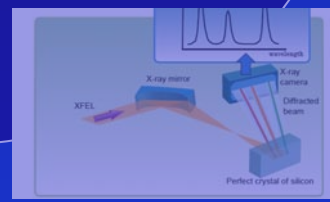


Photon Beam Conditioning



Photon Beam Diagnostics

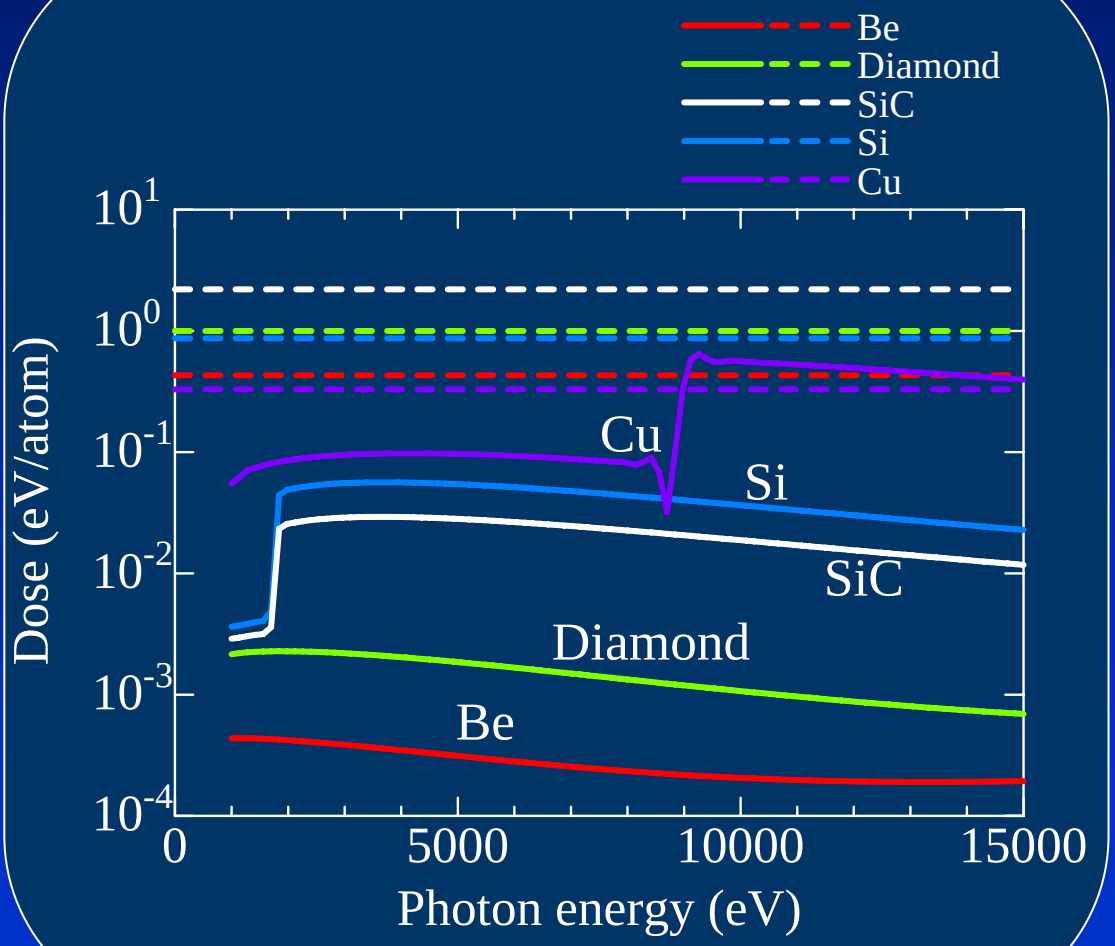




3rd gen. SR

VUV FEL

Dose



Parameters:

7.6e11 photons/pls

Source size: 50 um ϕ

Divergence: diffraction limited

e.g. 0.4 urad @ E=12.4 keV

Distance: 100 m

No Problem

Melt ??

Diamond, Be

SiC

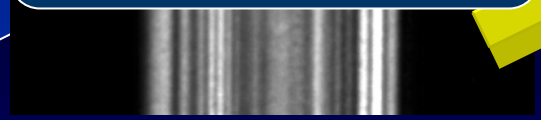
Si

Cu

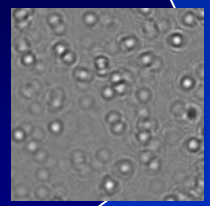
Photon Optics for XFEL

XFEL

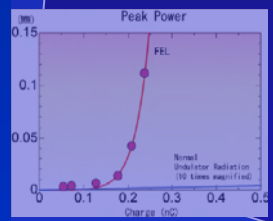
Dose
Spatial coherence

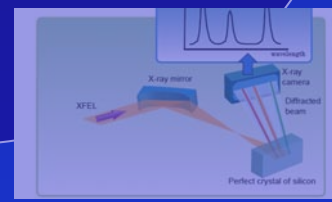


Photon Beam Conditioning



Photon Beam Diagnostics



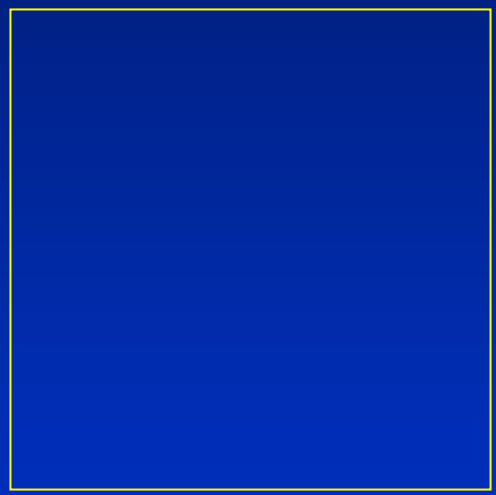


3rd gen. SR

VUV FEL

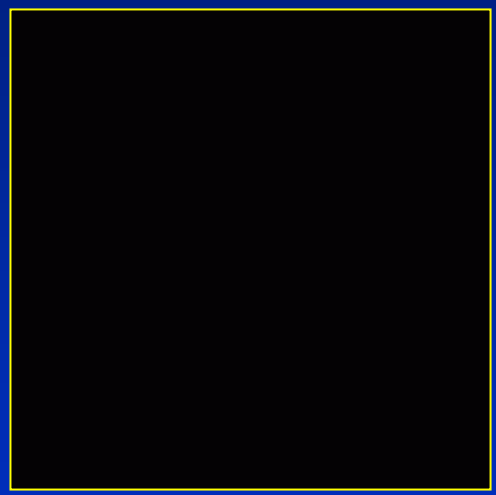
Coherence

Single electron



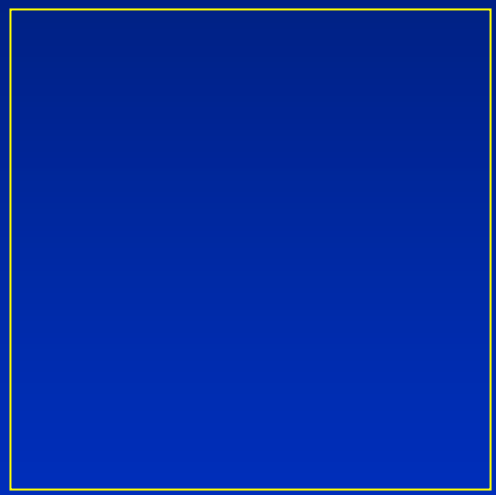
Coherence

Single electron



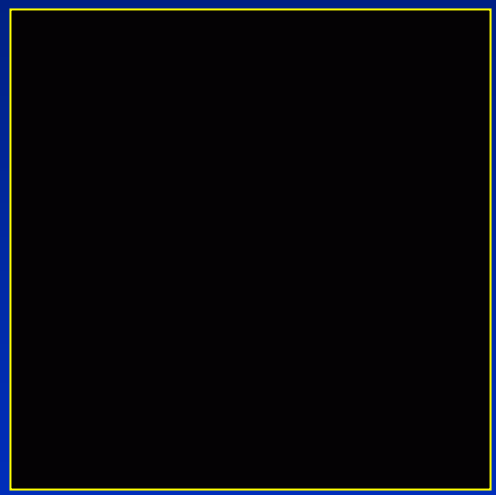
Temporal Coherence

Point source,
Many electrons
in random phase
(Chaotic source)



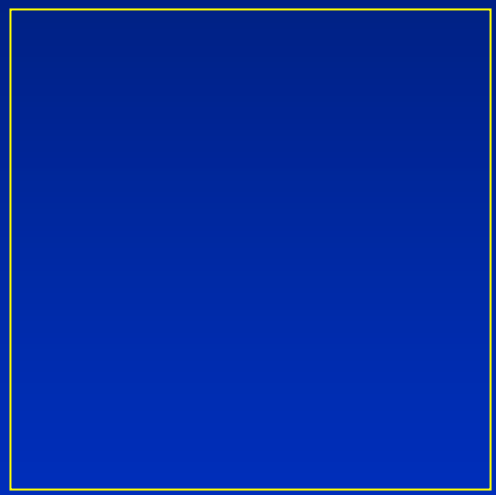
Temporal Coherence

Point source,
Many electrons
in random phase
(Chaotic source)



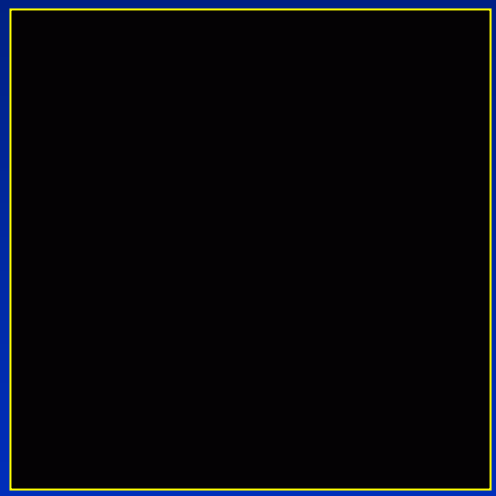
Spatial coherence

Planer source,
Many electrons
in random phase
(Chaotic source)



Spatial coherence

Planer source,
Many electrons
in random phase
(Chaotic source)

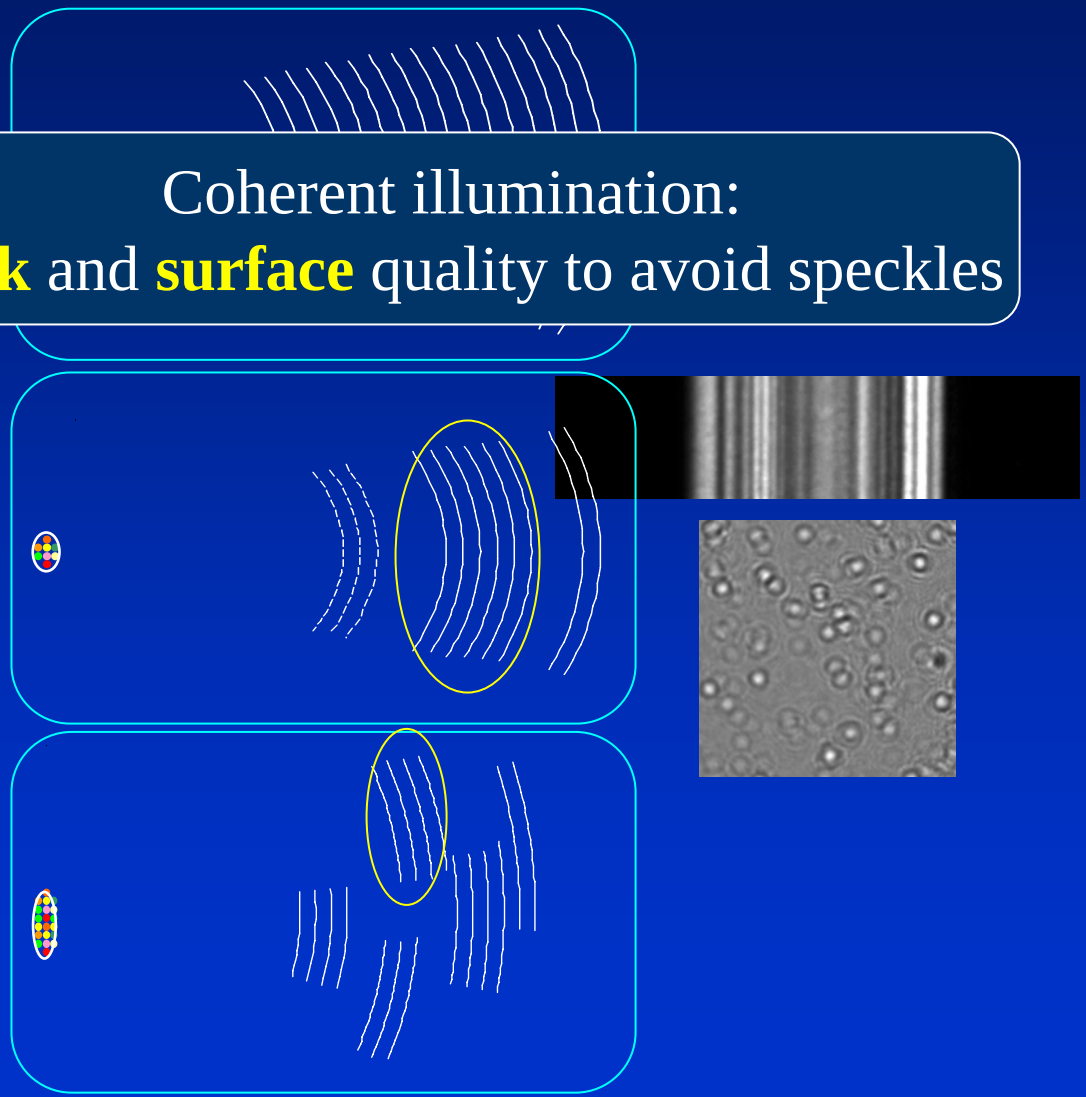


Wave field

Coherent illumination:
Bulk and **surface** quality to avoid speckles

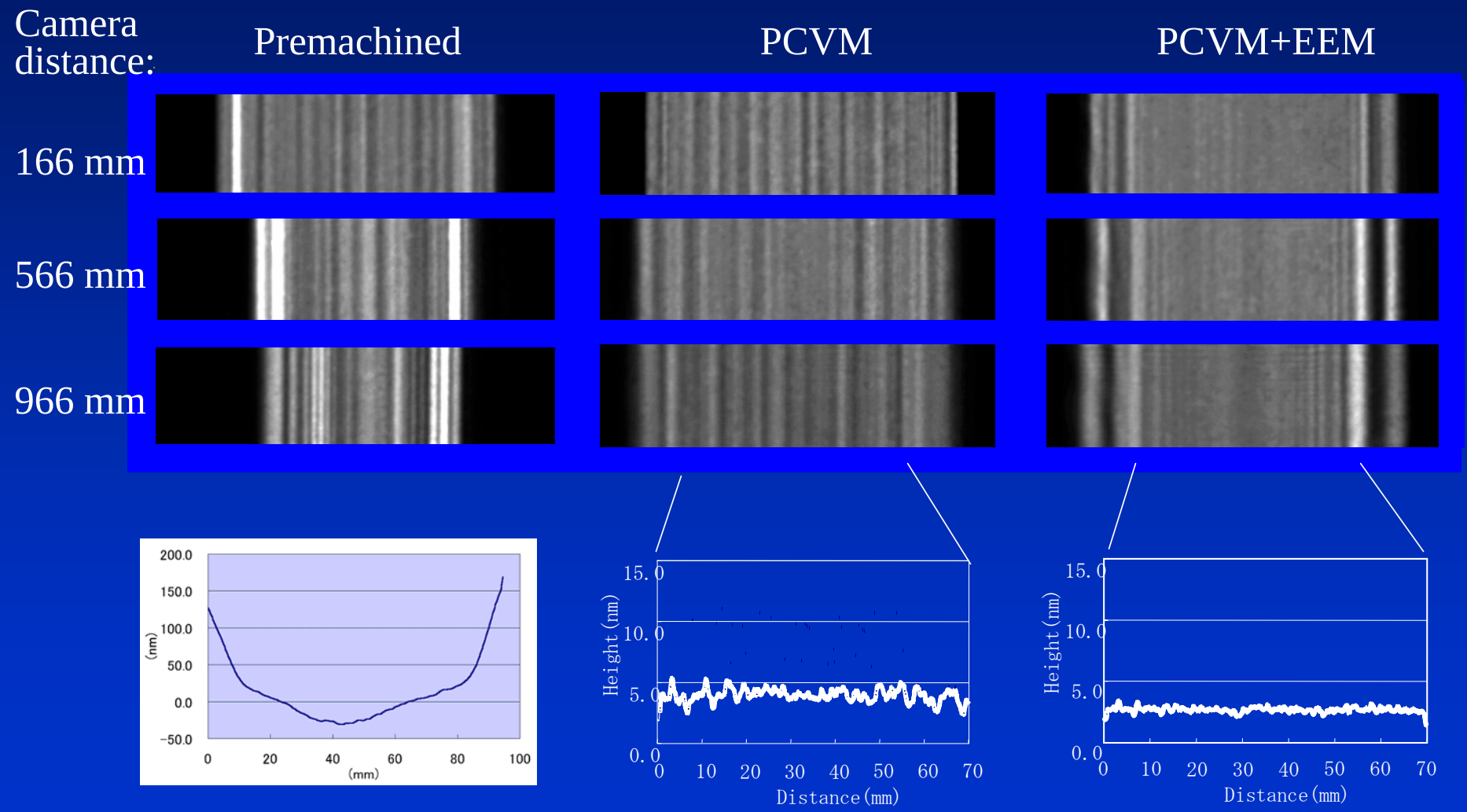
SASE-FEL

SR



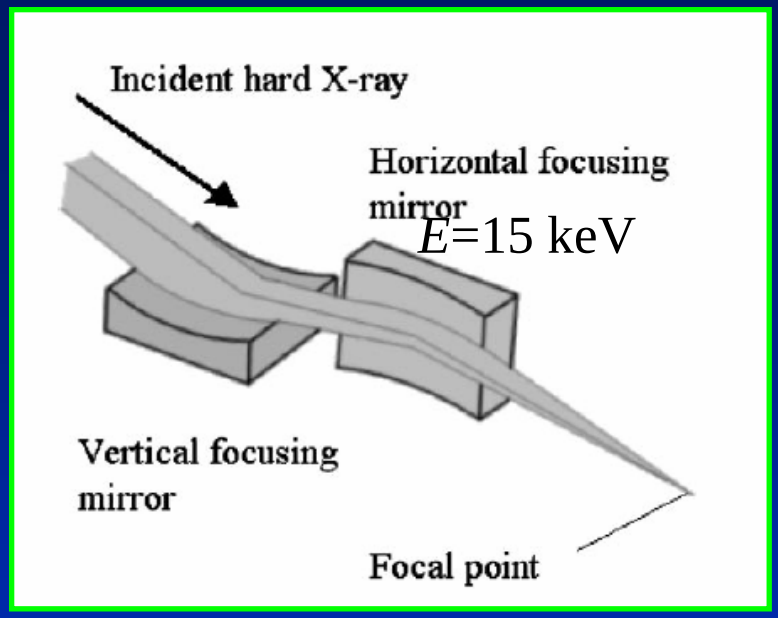
Mirror: SP8 - Osaka Univ. collaboration

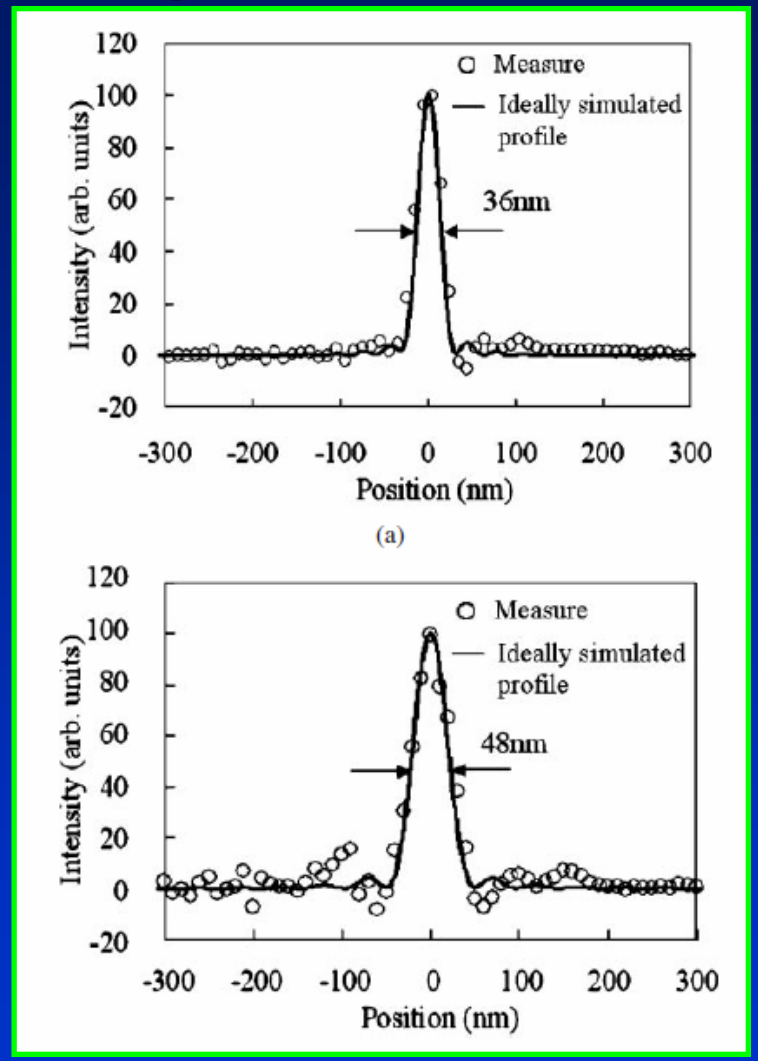
Mirror: Silicon (001) / Incident angle 1.2 mrad / Mirror length 100 mm



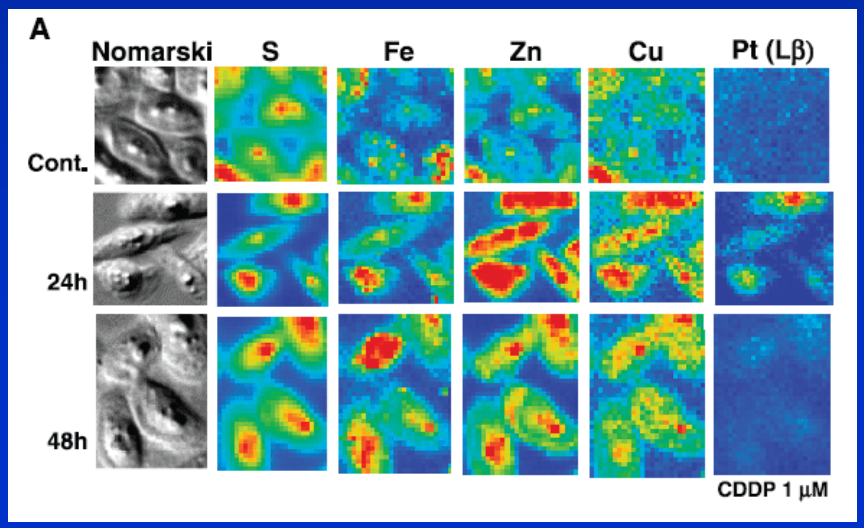
Y. Mori *et al*, *Proc. SPIE* (2001)

Nano focusing





Mimura et al., JJAP, **44** (2005) L539



Shimura et al., Cancer Research, **65** (2005) 4998

Monochromator

Bandwidth $\Delta E/E$

XFEL : 6e-4

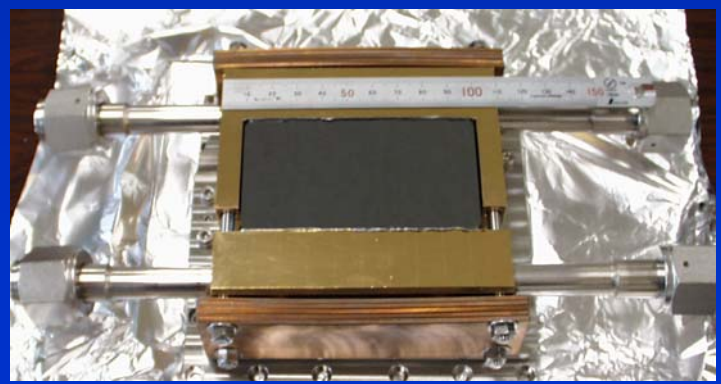
Silicon : 1e-4 with (111) Diamond: 6e-5 with (111)

8e-9 with (11 5 3) K. Tamasaku et al., J Phys. D **38** (2005) A61

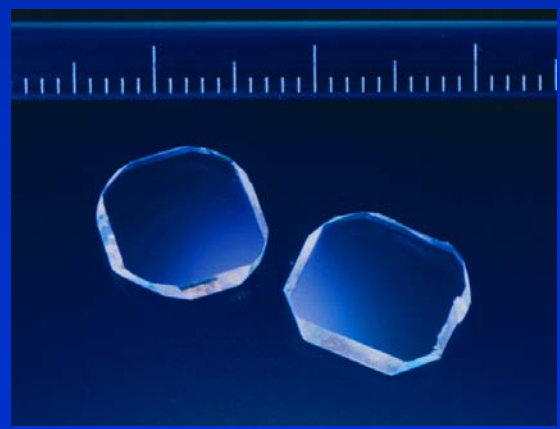
Yabashi et al., RSI **72** (2001) 4080

Yabashi et al., PRL 87 (2001) 140801; PRL 88 (2002) 244801

Single-crystal silicon
with cooling holder

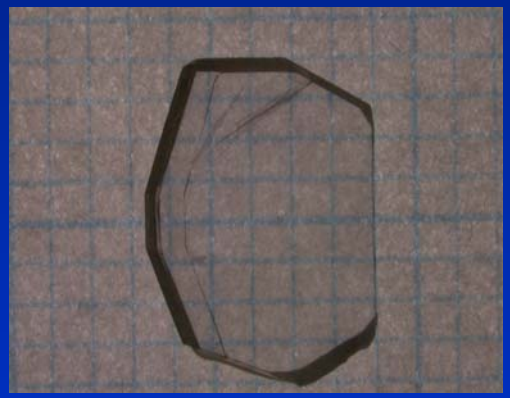


Single-crystal diamond: Type IIa
Collaborated with
Sumitomo Electric Industry

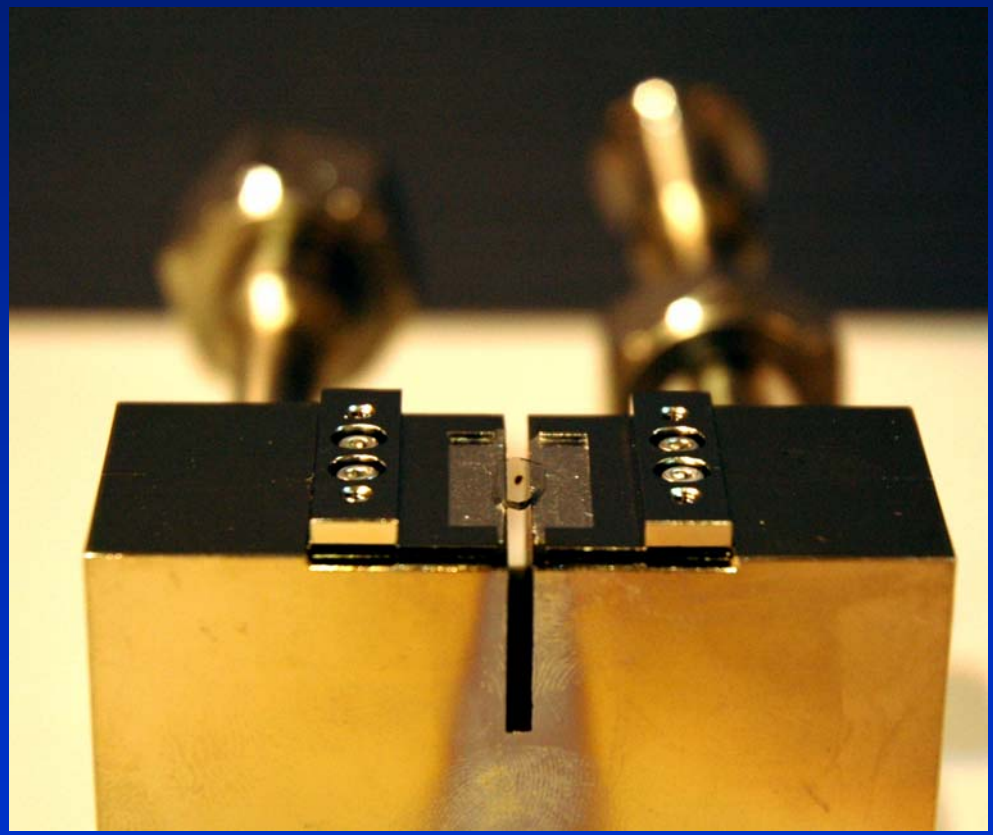


Diamond monochromator

(111)



5 mm

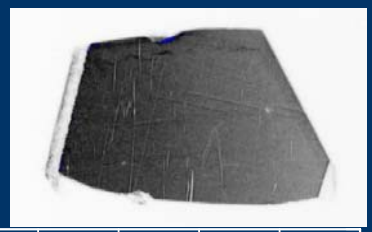


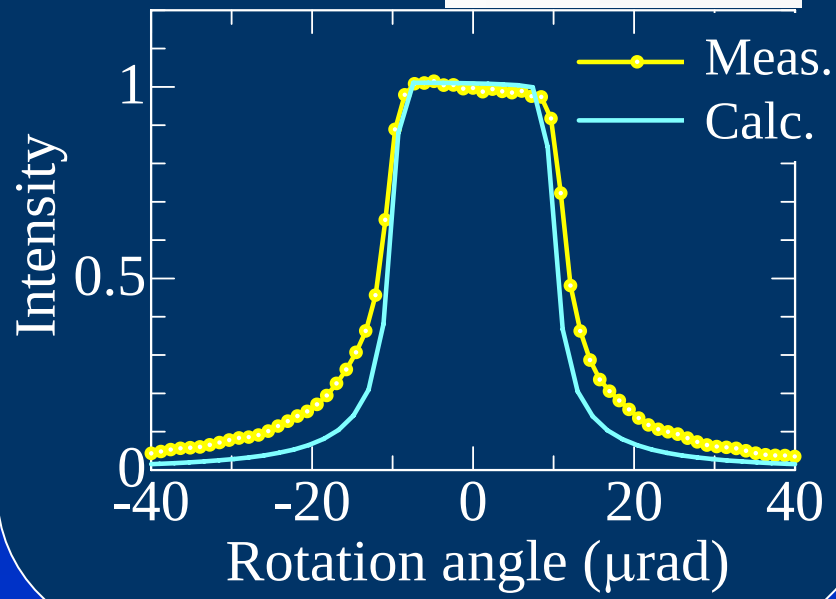
Diamond attached on Cu holder

Diamond monochromator

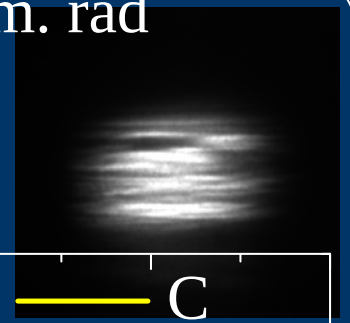
M. Yabashi et al., Proc. SRI 2006 (in press)

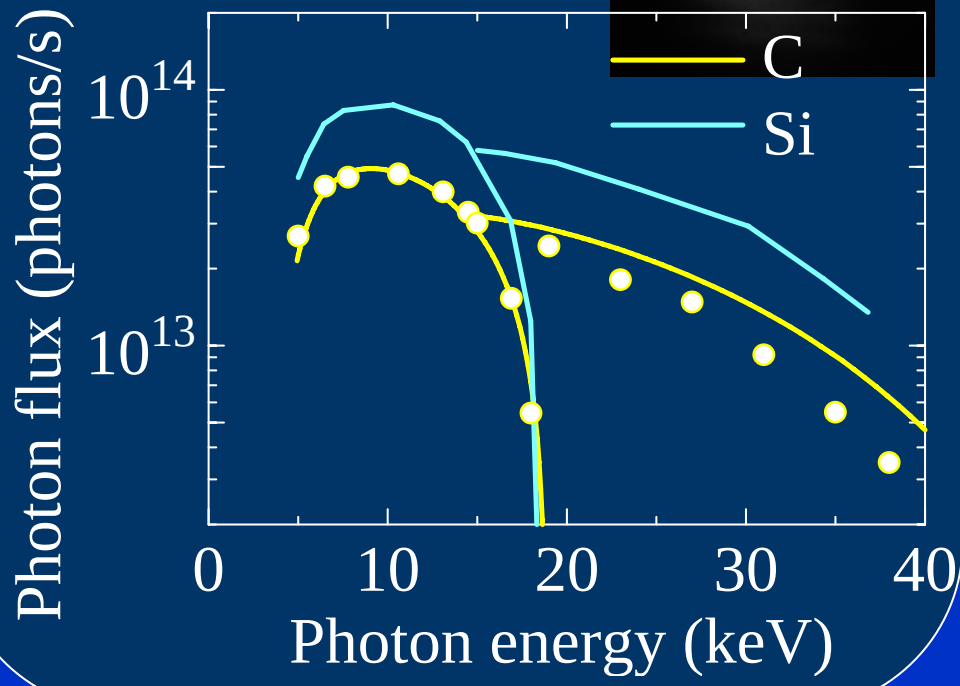
(111) polished crystals
~8x4x0.4 mm^3
@ 1km BL





I_b = 100 mA, ε = 3 nm. rad
@ BL39XU



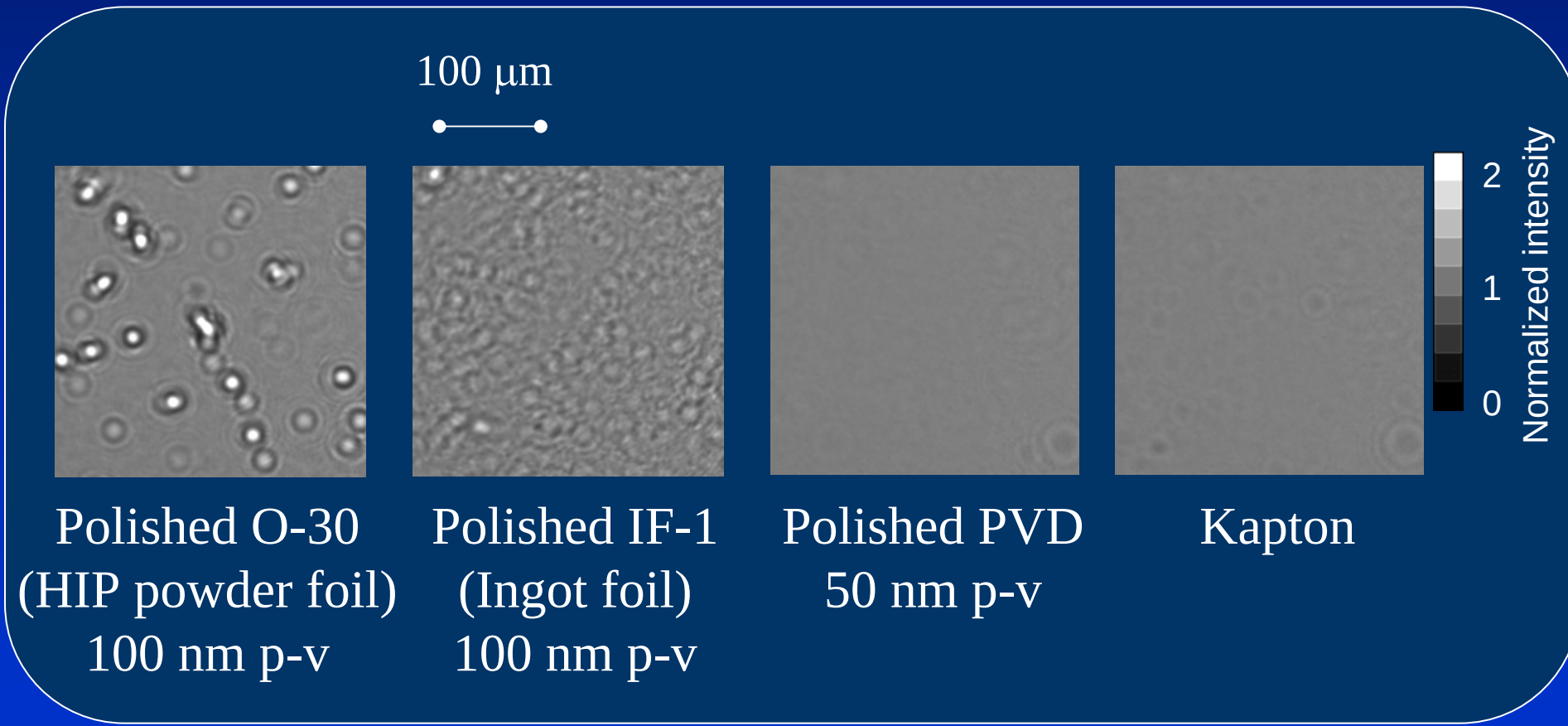


Surface polish is required for improving image quality

Be window

S. Goto et al., AIP conf. proc. **705** (2004) 405;
S. Goto et al., Proc. SRI 2006 (in press)

@1-km beamline (29XU), E=12.4 keV, d= 1400 mm

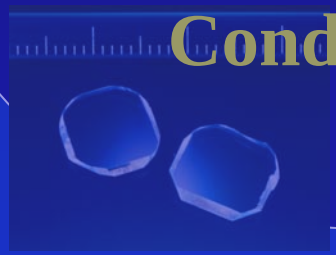


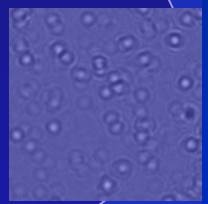
Photon Optics for XFEL

XFEL

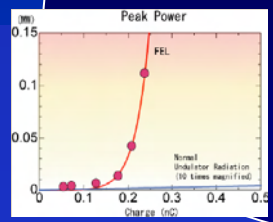
Energy spectrum

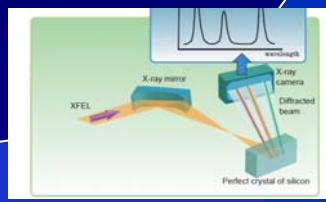
Photon Beam Conditioning





Photon Beam Diagnostics

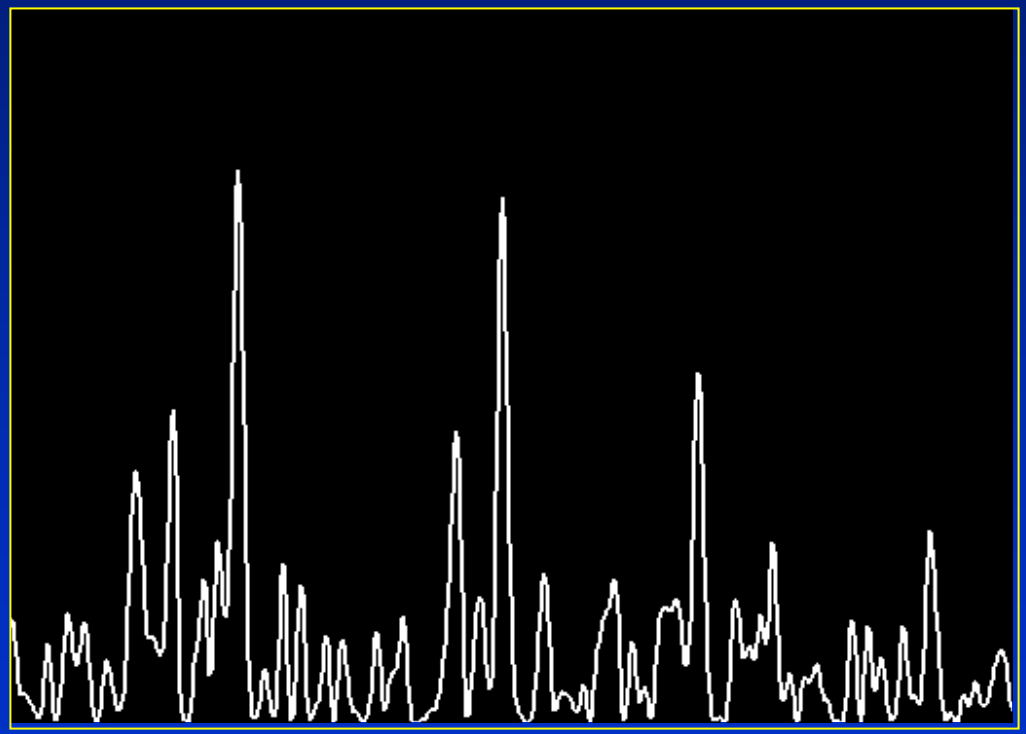




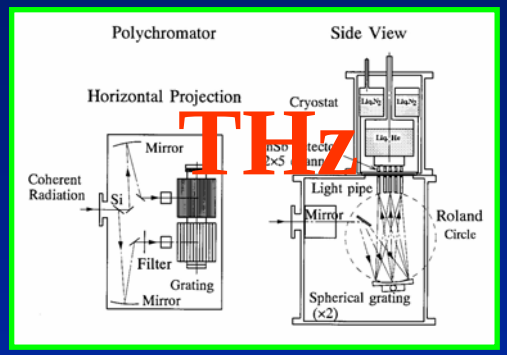
3rd gen. SR

VUV FEL

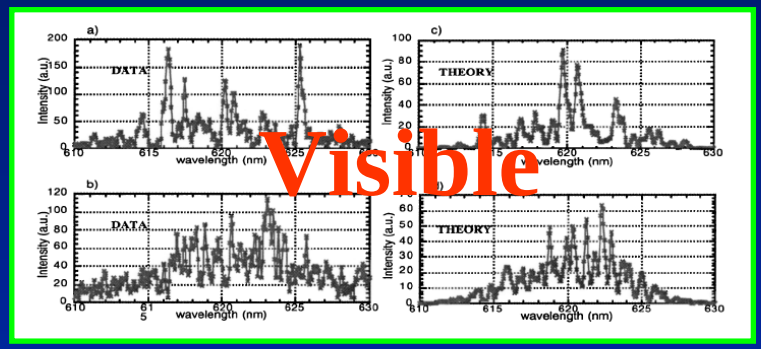
SASE fluctuation



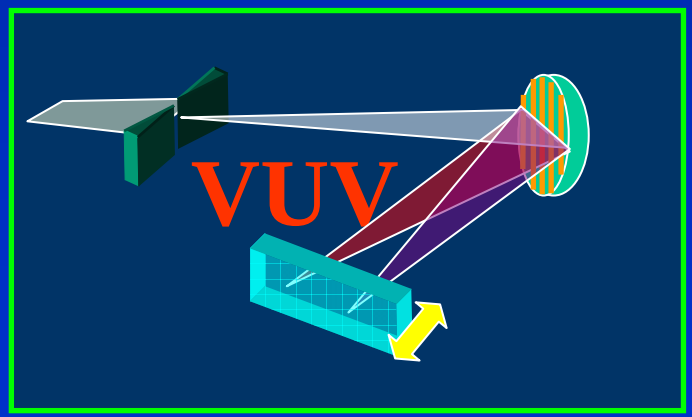
Single-shot spectrometer



T. Takahashi $\lambda \sim 1$ mm (THz)
杉山、東北大学科学計測研究所報告48 p. 1 (1999).



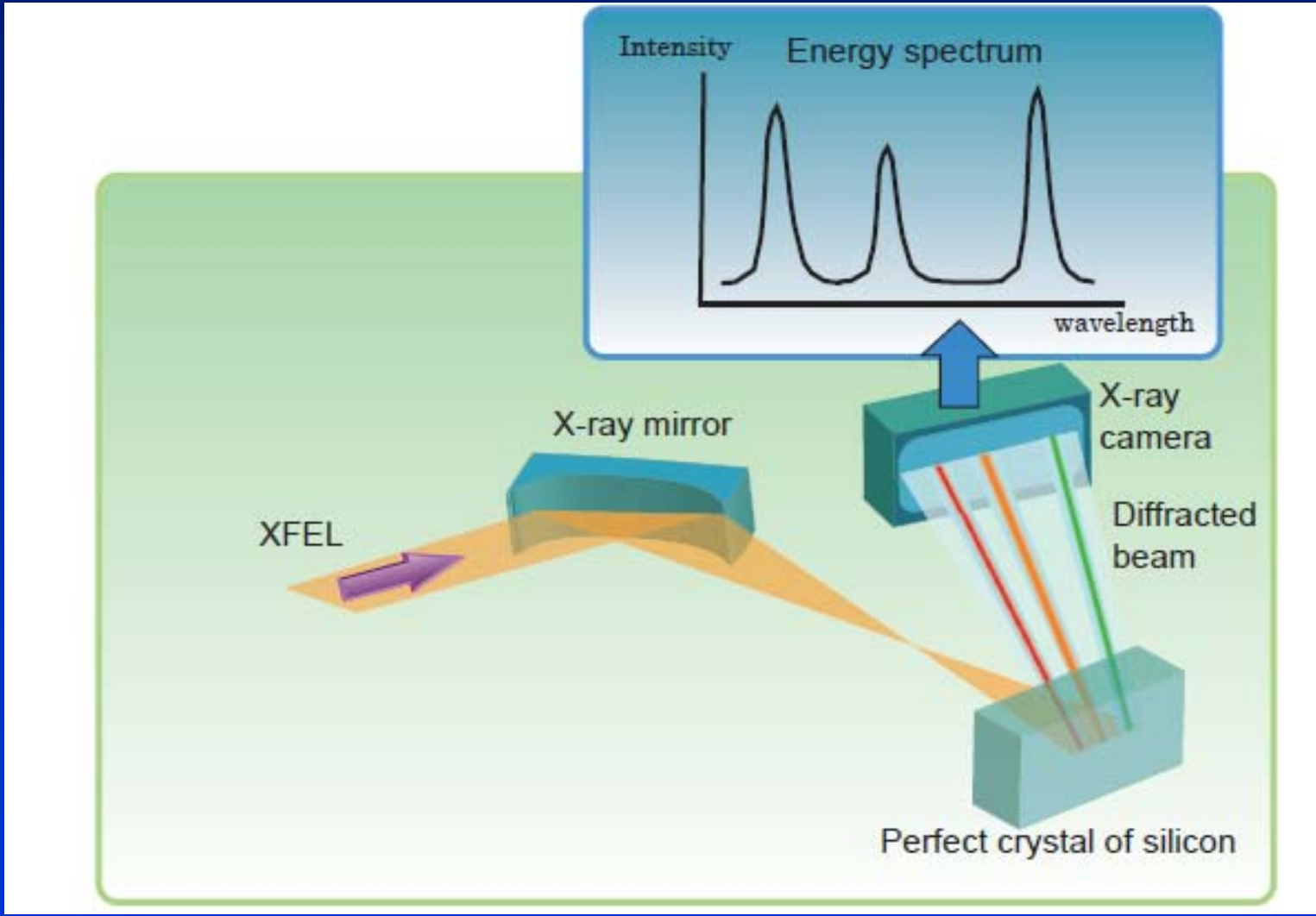
NSLS ATF (S-band linac + Wiggler)
$\lambda \sim 620$ nm
P. Catravas et al. PRL 82 (1999) 5261



SCSS Prototype Accelerator
DESY TTF, PRL **86** 104802 (2002)

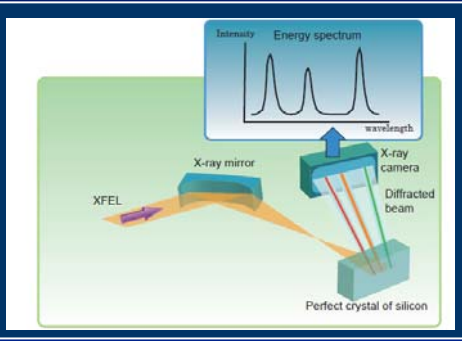
X-ray ??

Single-shot spectrometer

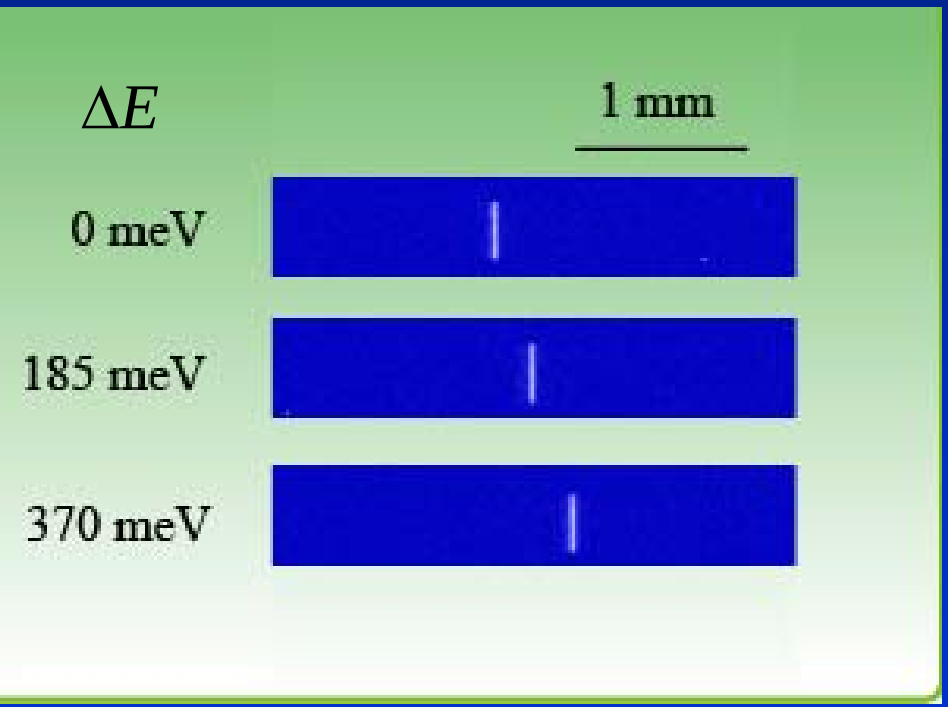


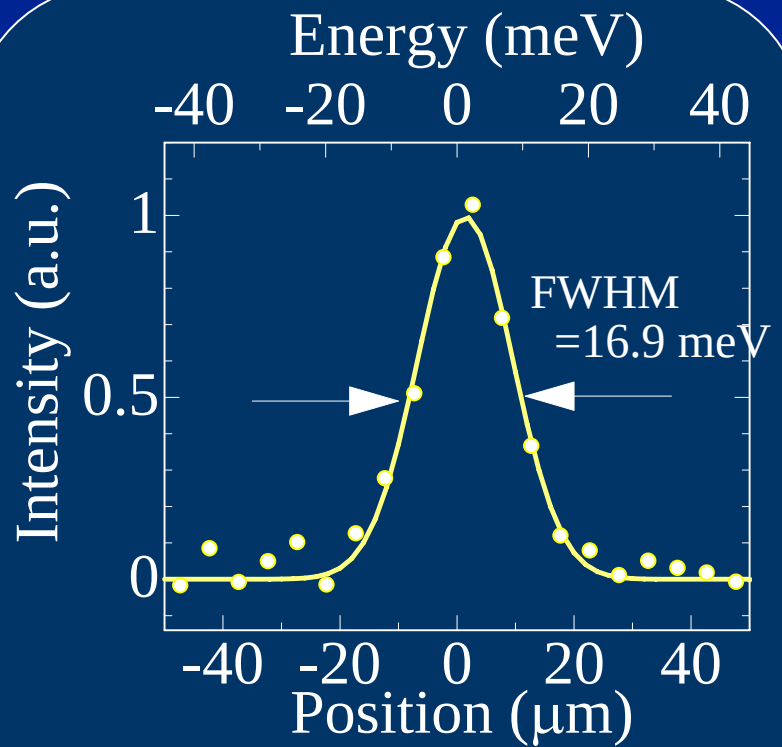
Result

Si 555 Mono +



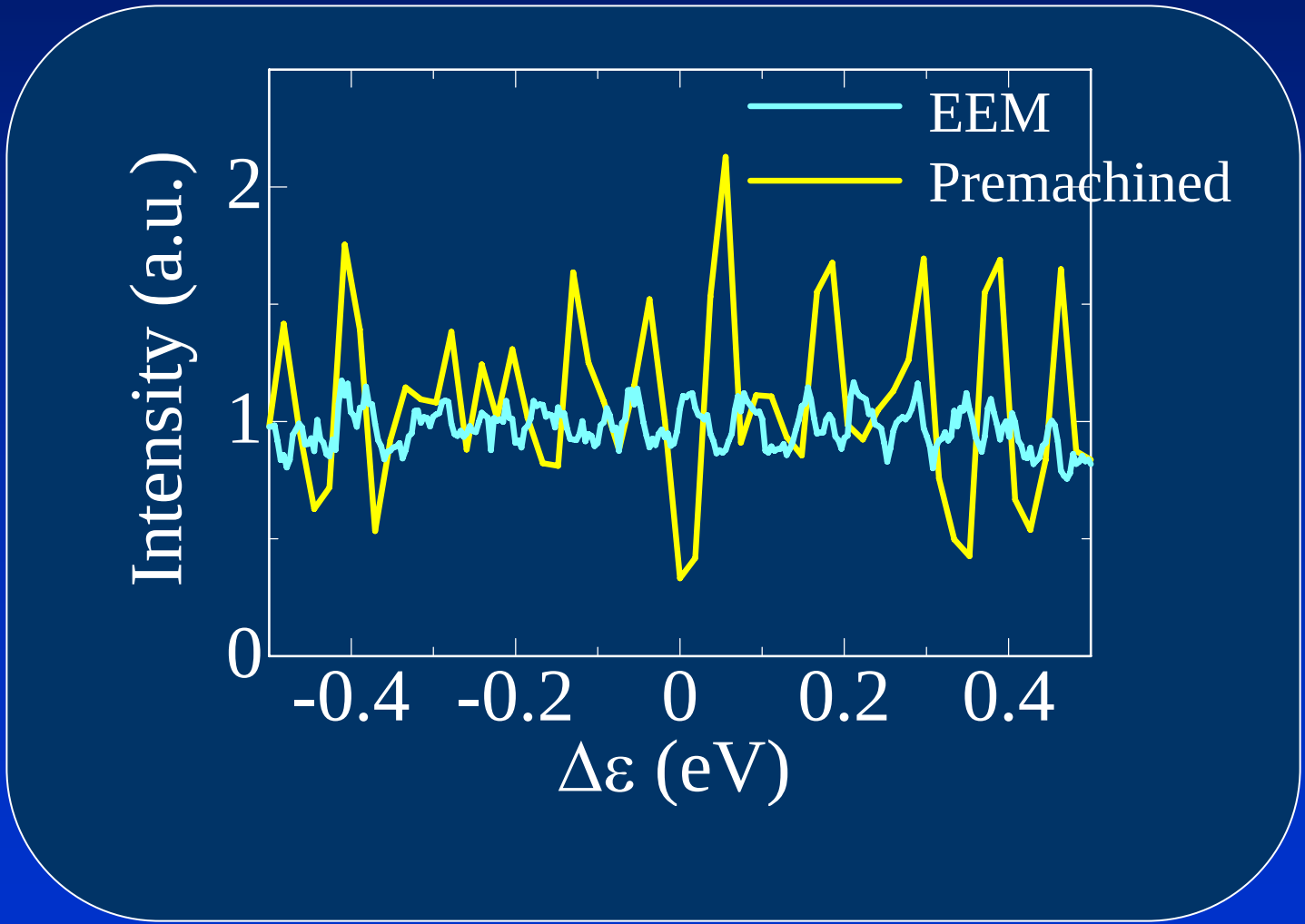
@ 1 km BL
E = 10 keV
Si 555





ΔE = 13.1± 1.9 meV

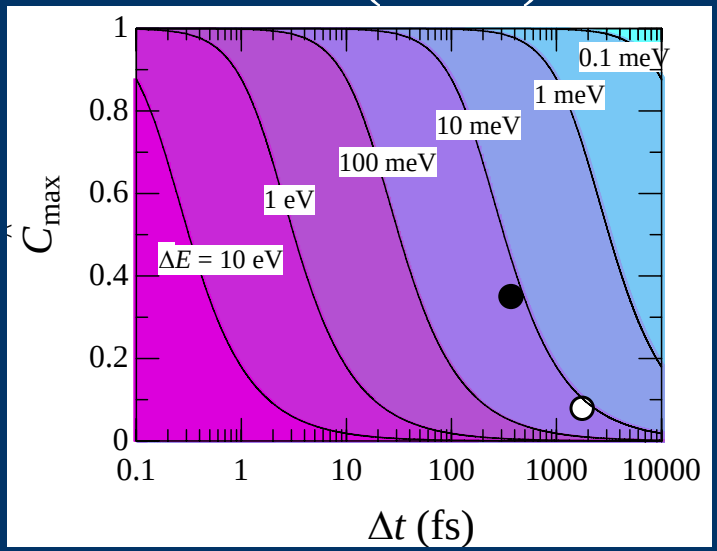
Mirror quality



Application

Temporal domain

$$\Delta E \cdot \Delta t = (const)$$



$\Delta t \leq$ a few ps

Low resolution

Diagnostics of e-beam energy
Tuning of undulators ...

Si (111): $\Delta E_T \sim 100$ eV
@ $E = 10$ keV
$\Delta E_T / E = 0.01$

PRL 97, 084802 (2006) PHYSICAL REVIEW LETTERS week ending 25 AUGUST 2006

Single-Shot Spectrometry for X-Ray Free-Electron Lasers

Makina Yabashi,[1,5,*] Jerome B. Hastings,[2] Max S. Zolotorev,[3] Hidekazu Mimura,[4] Hirokatsu Yumoto,[4] Satoshi Matsuyama,[4] Kazuto Yamauchi,[4] and Tetsuya Ishikawa[1,5]

Summary

- VUV diagnostics
  - Single-shot spectrometer: $\Delta\lambda/\lambda$ = 0.4 % @ λ =59 nm
  - Spatial profile, coherence
  - Radiation energy: ~μJ, need transparent gas detector for user operation (by M. Richter)
- X-ray Handling
  - Mirror: Speckleless, Nanofocusing; Low-Z coat, Large area
  - Diamond: Flux OK, Image need to more development
  - BeW: Polished PVD OK
- X-ray Diagnostics
  - Single-shot spectrometer