Why we want a flat electron beam from a photocathode gun?

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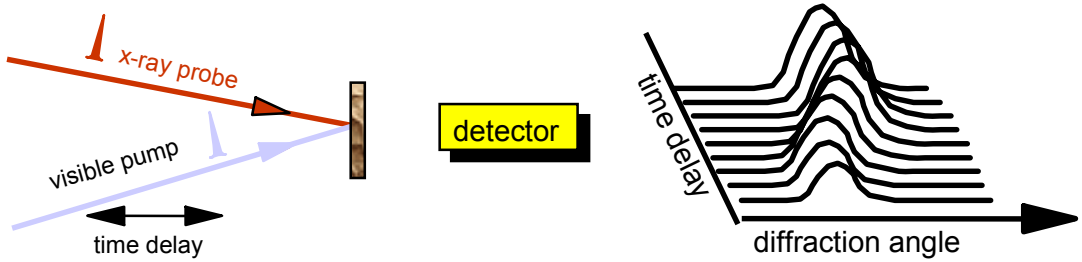
for a Berkeley team

Motivations

Studies of structural dynamics on a time scale of ~ 100 fs

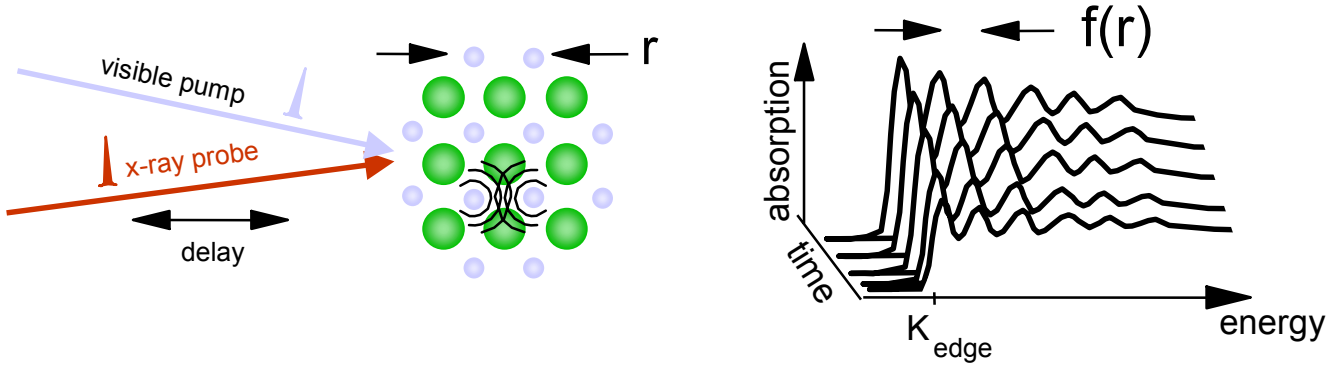
(atomic vibrational period=1 Å / (speed of sound)=100fs)

time-resolved x-ray diffraction



phase transitions of ordered crystals

time-resolved EXAFS



chemical reactions

Motivations cont'd

Investigate atomic motion associated with:

- Phase transitions in solids
- Surface dynamics
- Making and braking of bonds during chemical reactions
- Rapid biological processes

  → chemical dynamics in proteins

Motivations

Static (time-averaged) structural information

↓

World-wide, ~ 70 SR sources, cumulative investment ~$10B

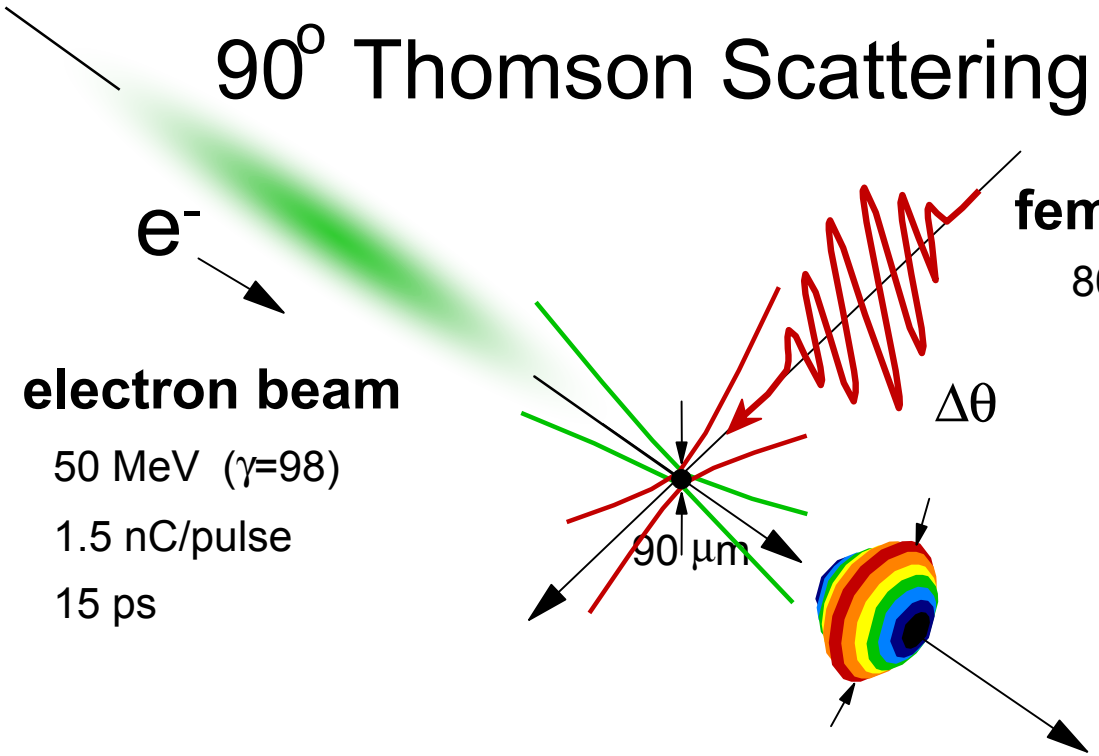
cont'd

Dynamic structural information (on a time scale on which atom moves, ~ 100 fs)

↓

R&D in various places

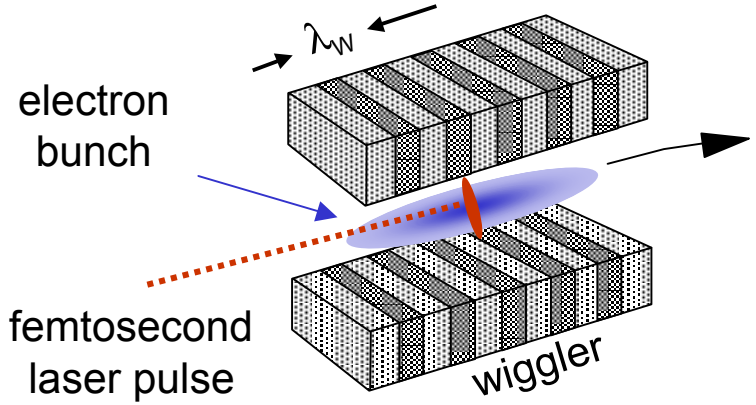
LBNL roadmap

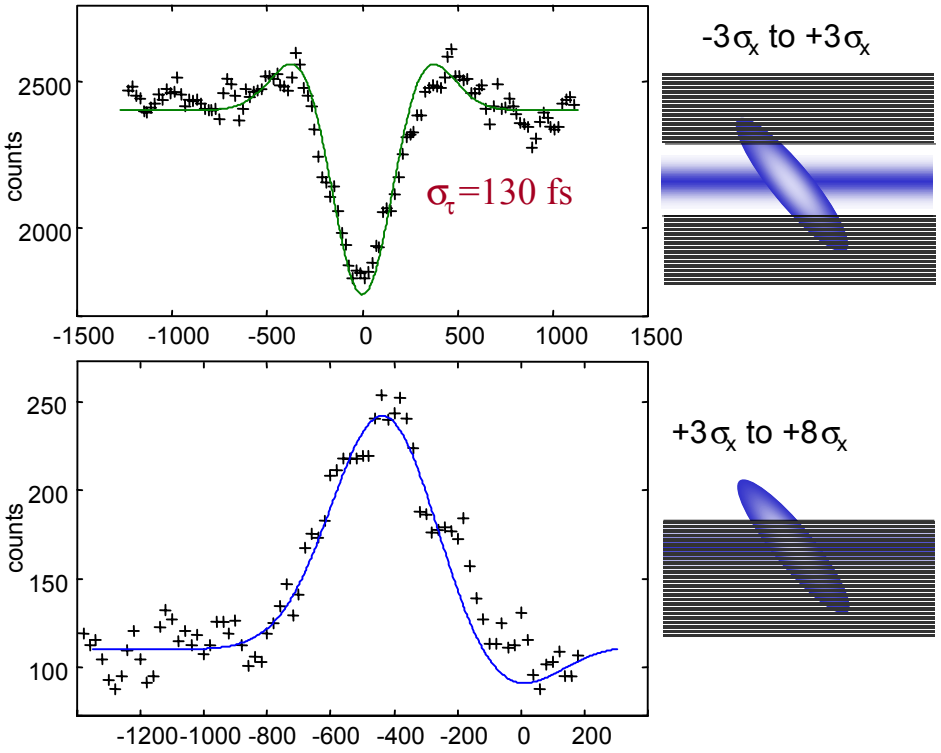


Proposed by:
S. Chattopadhyay, K.-J. Kim, C. Shank
Experiment by:
W. Leemans , R. Schoenlein et. al.

LBNL roadmap cont'd

Laser-electron beam slicing





100 fs
1.5 Å (8 keV)
3×10^5 ph/sec/0.1% BW
(10^2 ph/pulse)
$\Delta\theta$ ~0. mrad

Proposed by:
A. Zholents, M. Zolotorev, PRL, 76, (1996)912
Experiment by:
R.W. Schoenlien et. al., Science, March 24, 2000

Preferable repetition rate of ultra-fast x-ray experiments is ~ 1 -10 kHz

Structural dynamics, such as phase transitions, chemical reactions, surface processes, protein dynamics, are not cyclic or reversible.

The time interval between x-ray pulses must be sufficient to allow replacement or flow of the samples.

Even in material systems in which the original structure does recover, the recovery time is typically long.

Bright electron beams from a photocathode gun:

(BNL, SLAC, LANL, UCLA, FNAL, Boeing, CERN, DESY, …)

Q=1nQ,

transv. emit. = 2×10^{-4} cm,

long. emit.=8×10^{-3} cm (10 ps, 15 keV)

Brightness = 2×10^{19} electrons/cm^3

Compare with the ALS beam:

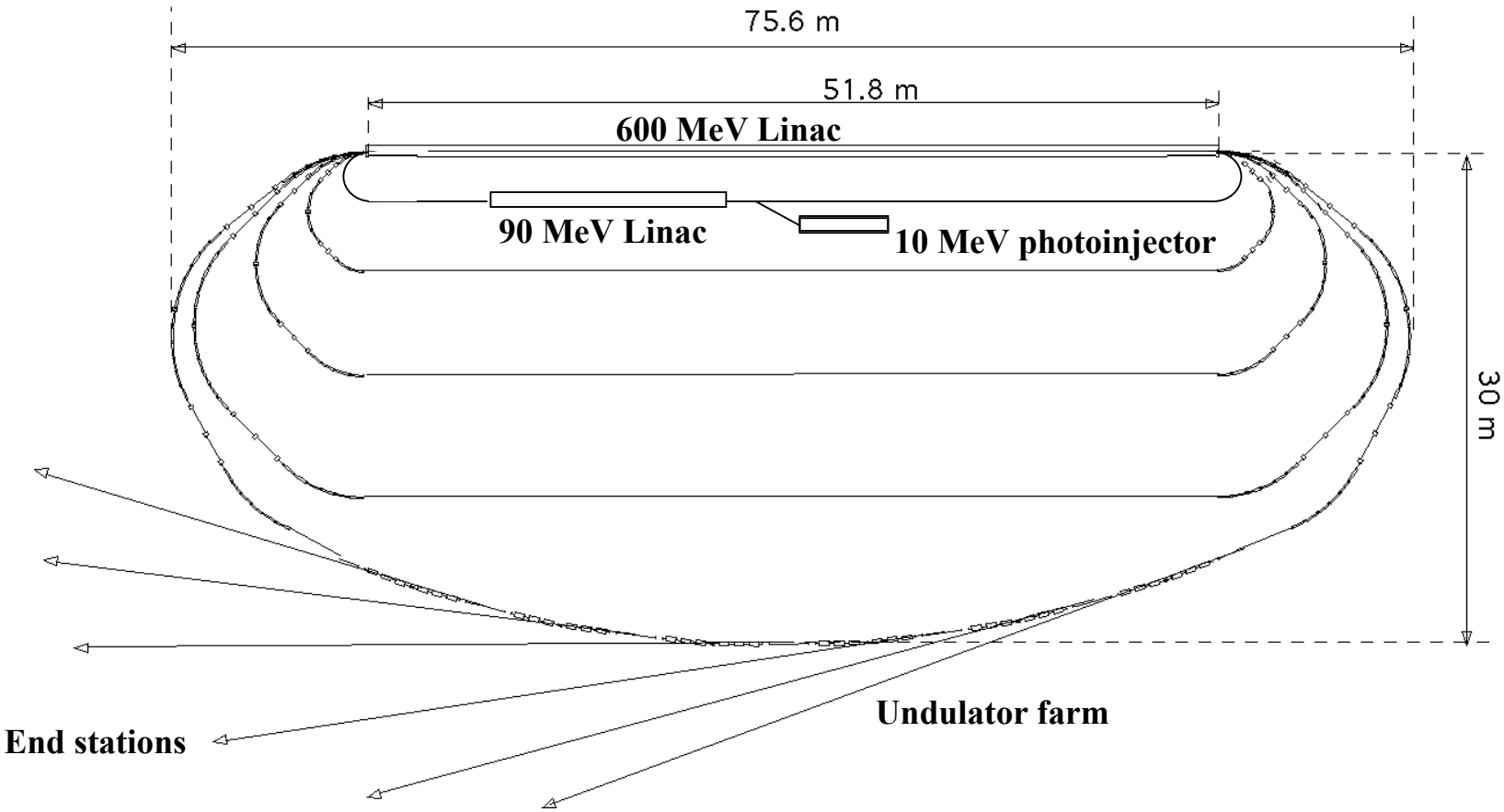
Q=1nQ,

transv. emit. = 1.5×10^{-3} cm / 3×10^{-5} cm ,

long. emit.=1.5 cm (15 ps, 1900 keV)

Brightness = 1×10^{17} electrons/cm^3

A Schematic of a 2.5 GeV Recirculating Linac Facility



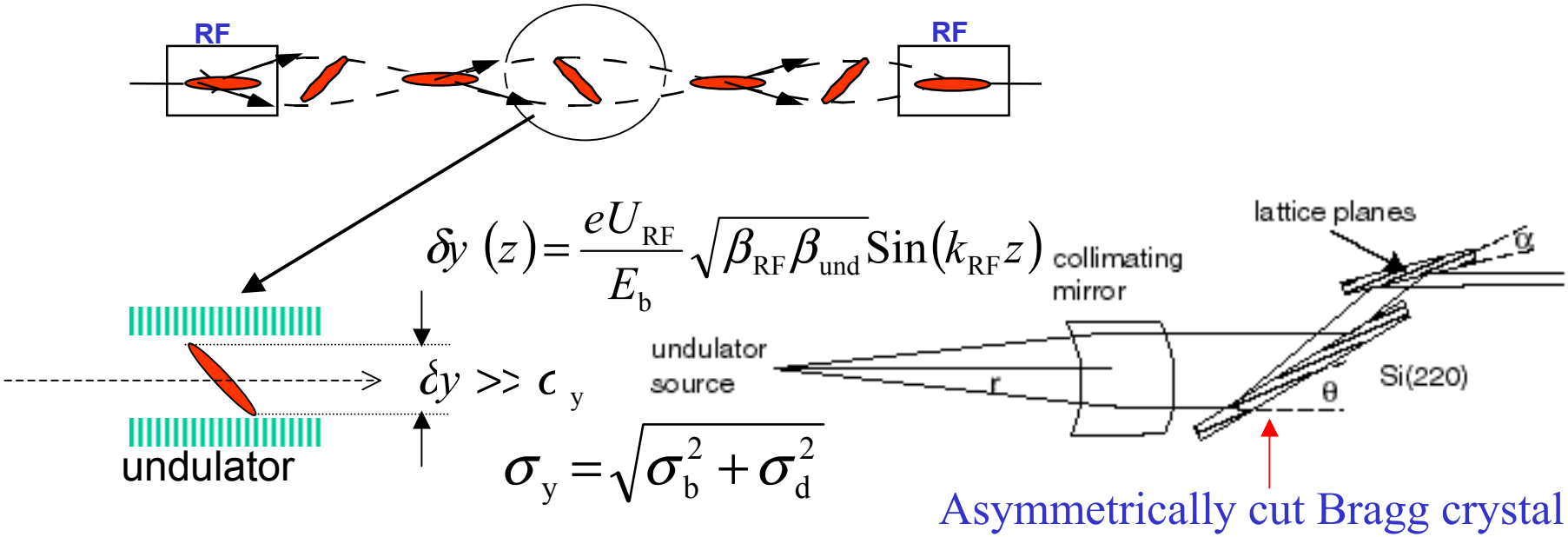
Two stages of pulse compression:

a) electron beam: 10 ps → 1 ps

b) x-rays: 1 ps → 100 fs

Compression of x-ray pulses

is possible due to a correlation between the longitudinal and transverse positions of electrons inside the electron bunch created by the RF orbit deflection in a cavity in the beginning of the final straight section.



Diffraction limited size of a source at λ¬1Å: σ_d ~3 μm

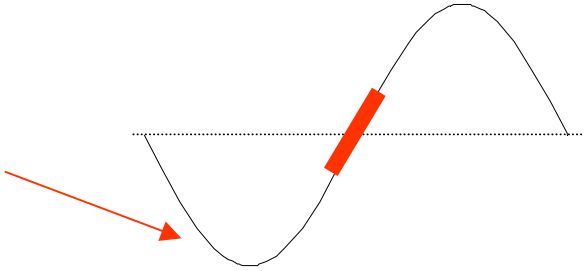
Beam size at ε_n=0.4 mm-mrad: σ_b ~14 μm

Compression of x-ray pulses cont'd

Example:

X-ray pulse length (FWHM): 60 fs

RF kicker voltage (at the peak): 6.6 MV



Beam height (FWHM): 400 microns

Number of slices: 30

Flat beam out of the gun with emittance ratio ~ 50 to 1

Proposed by Brinkmann, Derbenev, Flötmann

Tested on FNAL photoinjector A0 by Edwards and co-workers

Electron beam parameters from the injector

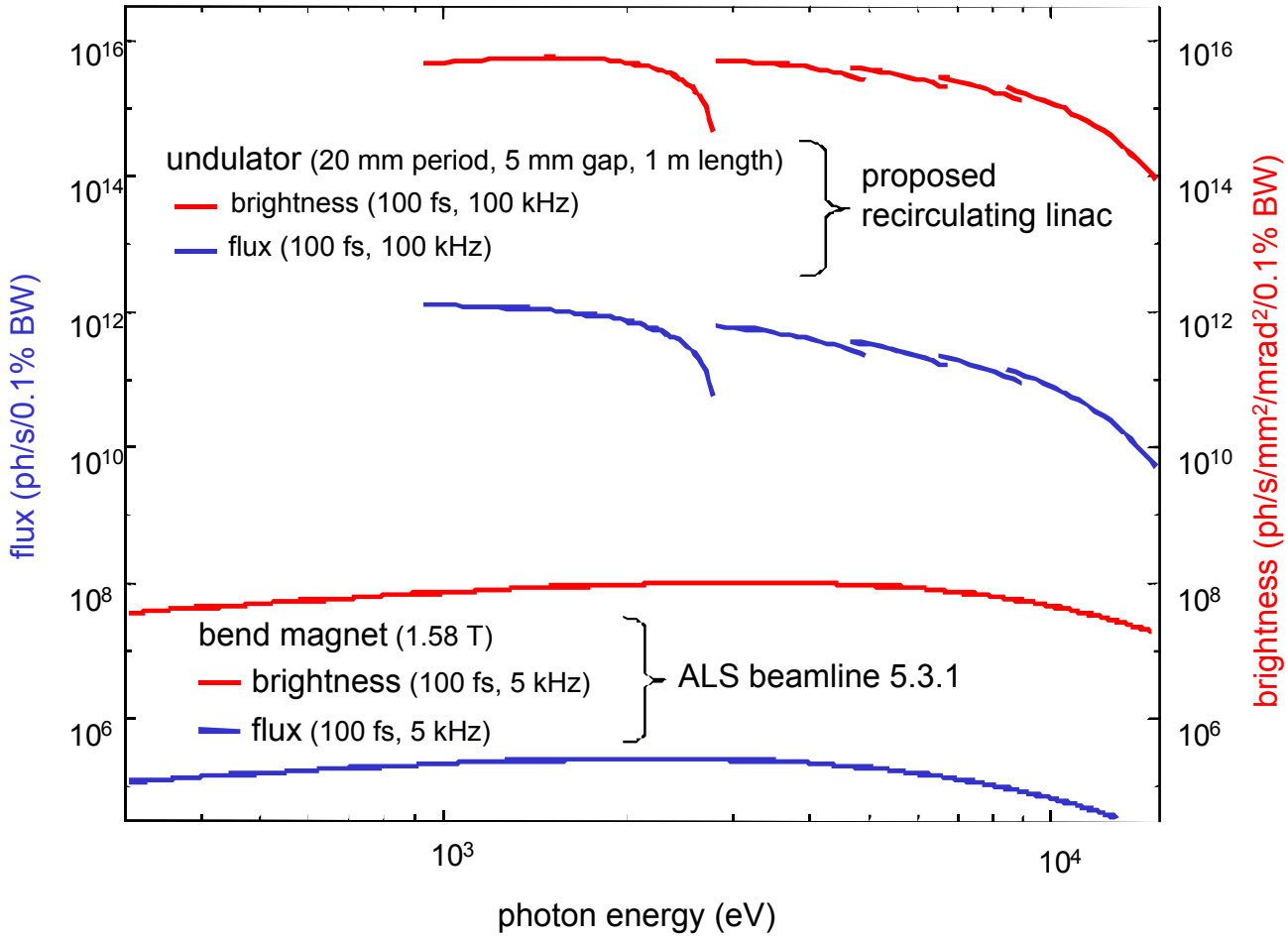
Energy	10 MeV
Charge	1 nC
Normalized rms horizontal emittance	20 mm-mrad
Normalized rms vertical emittance	0.4 mm-mrad
Energy spread at 10 MeV	15 keV
Pulse length (uniform distribution)	10 ps

The RF gun parameters:

RF frequency	1.3 GHz
Peak electric field on a cathode	70 MV/m
Repetition rate of injection pulses	1 - 10 kHz

Laser parameters:

Wavelength (3-rd harmonic of Ti:sapphire laser)	267 nm
Pulse energy	100 μJ
Pulse length (FWHM)	10 ps
Repetition rate	1-10 kHz



Average femtosecond flux and brightness compared with that of the existing bend-magnet fs beamline.