UVSOR FACILITY
INSTITUTE FOR MOLECULAR SCIENCE

Radiation from Laser-modulated and Laser-sliced Electron Bunches in UVSOR-II

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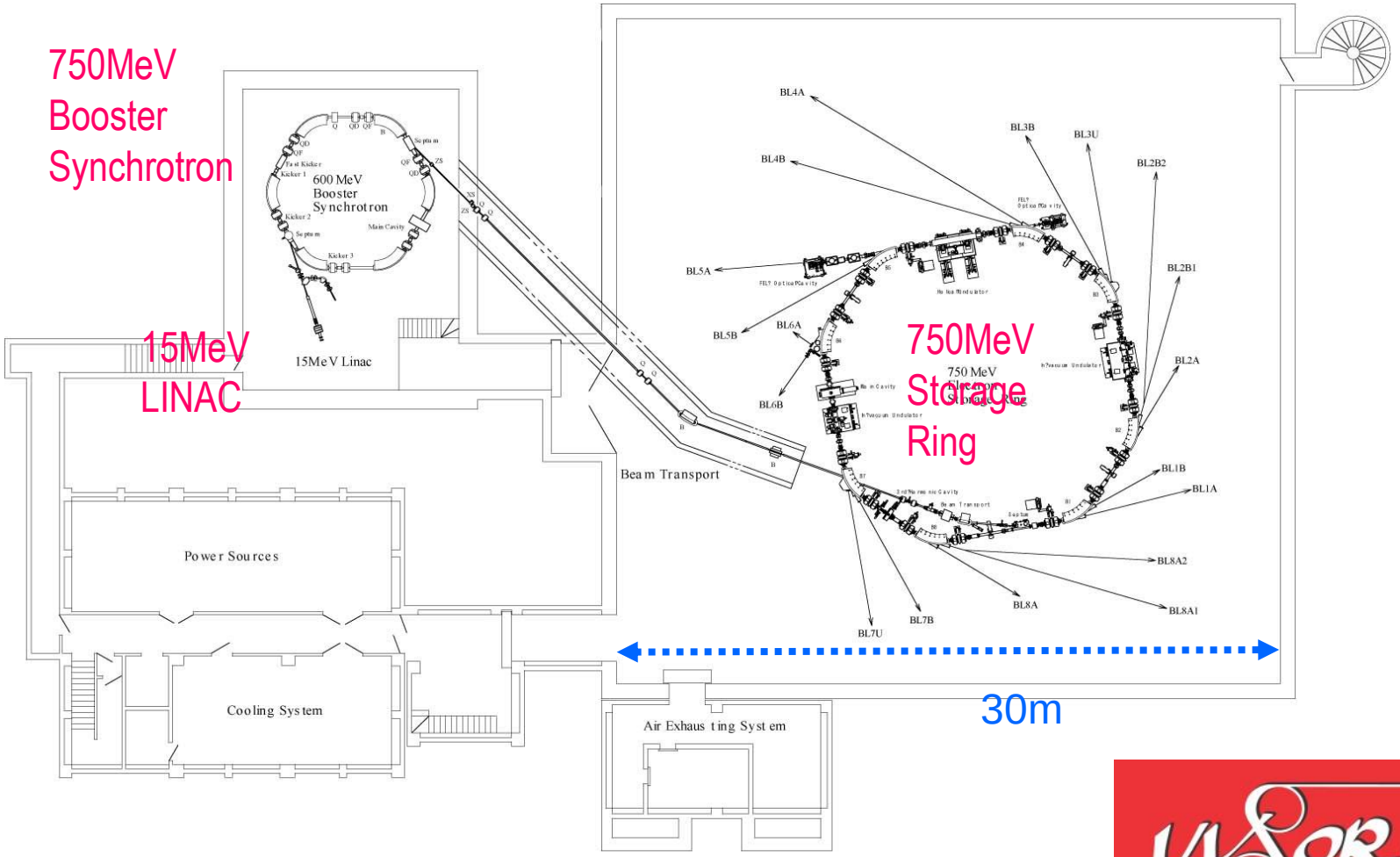
極端紫外光研究施設

UVSOR-II Storage Ring and SR Beam-lines

Electron Energy 750 MeV, Circumference 53 m

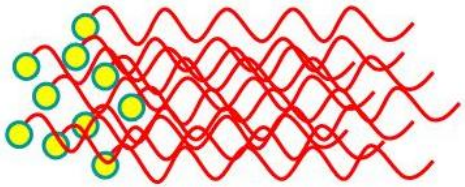
UVSOR Facility, Institute for Molecular Science
Okazaki, Japan



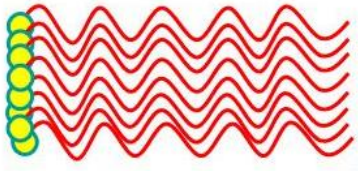
UVSOR since 2003

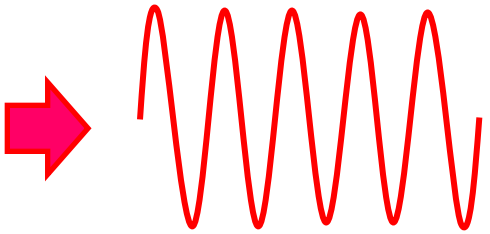
Coherent Synchrotron Radiation from Ultra-short e-Bunch

Normal Synchrotron Radiation



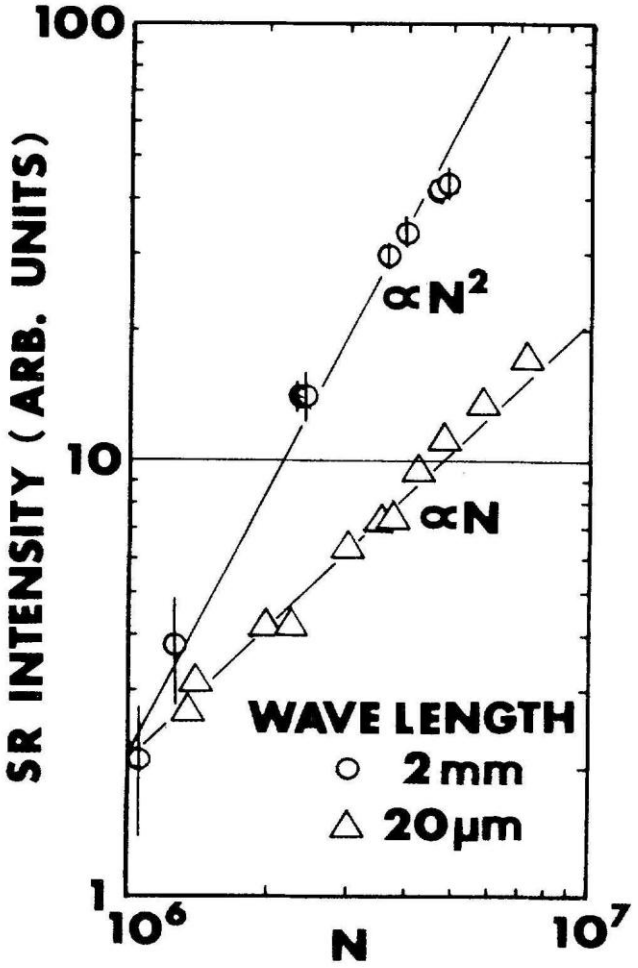
Coherent Synchrotron Radiation
from Ultra-short e-Bunch





First Observation of CSR

http://www.lns.tohoku.ac.jp/index.php



Nakazato et. al., PRL63 (1989)1245

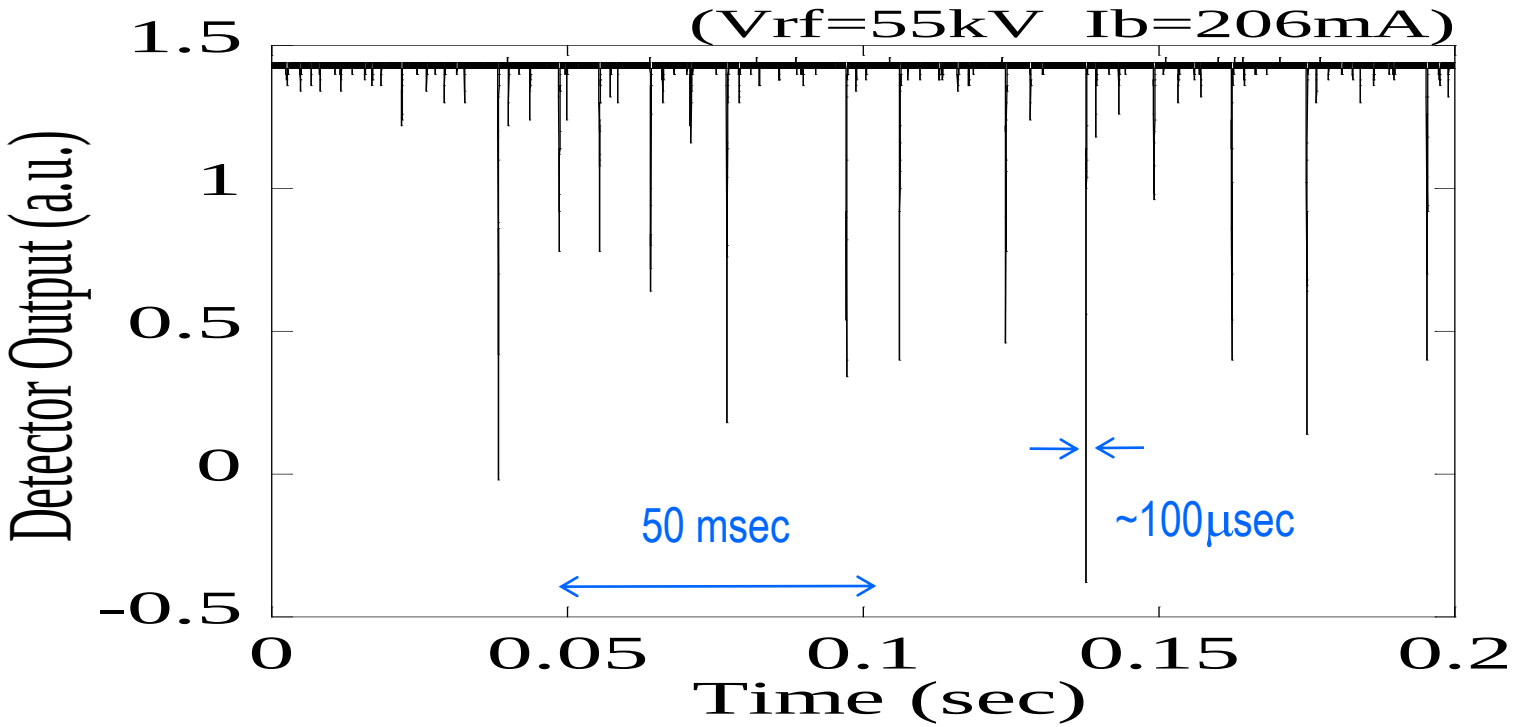
Coherent Synchrotron Radiation from Long Electron Bunches ?

$\sigma_z < \lambda \Rightarrow$ CSR

$\sigma_z > \lambda \Rightarrow$ No CSR?

THz Bursts at UVSOR-II

Y. Takashima, M. Katoh, M. Hosaka, A. Mochihashi, S. Kimura, T. Takahashi, Jpn. J. Appl. Phys. 44 (2005), L1131



High Peak Intensity ~ 10000 × normal SR ⇒ CSR?

?

Observed Wavelength << e-Bunch Length

0.2 – 3 mm ~ 50 mm

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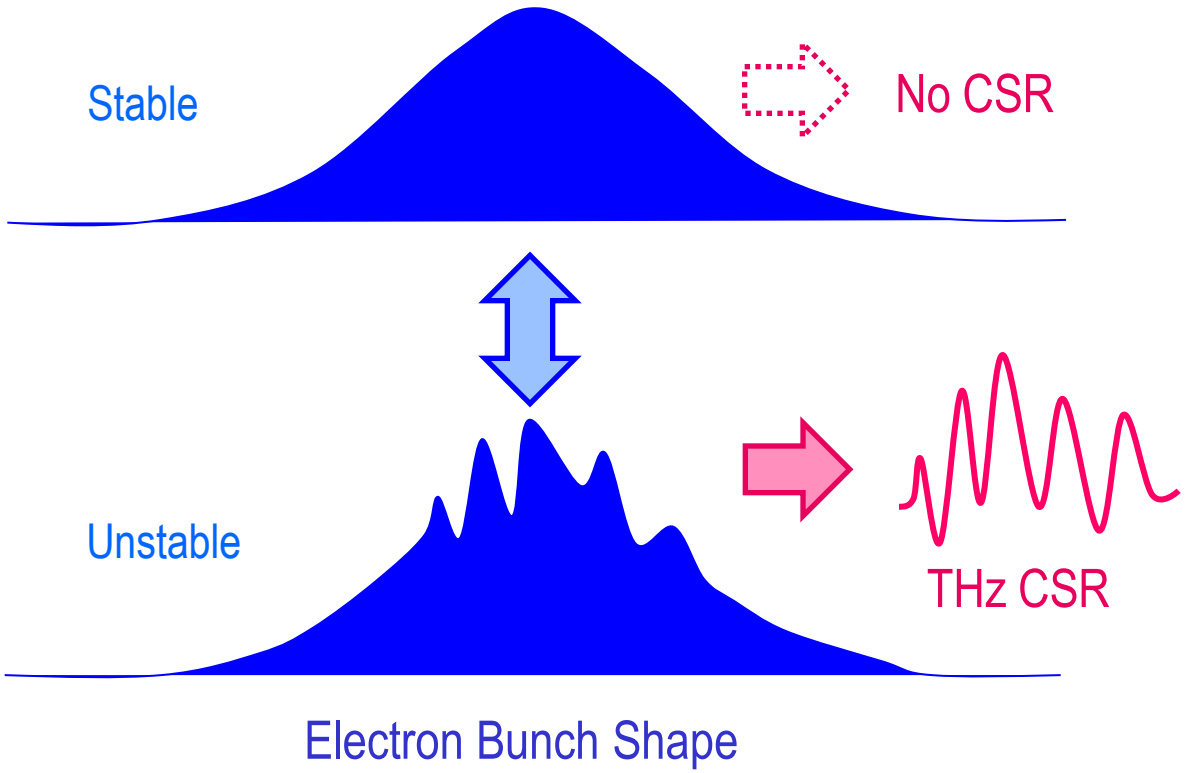
What is THz Burst?

- Very common phenomena in storage rings

  (MAX-I, NSLS-VUV, SURF, ALS, BESSY, UVSOR-II, NewSUBARU…..)

- CSR due to micro-density structure created by instability

  (*e.g.* G.Stupakov & S.Heifets, PRSTAB 5, 054402, 2002)



Coherent Synchrotron Radiation

SR Power emitted by an electron bunch

Normal (Incoherent) SR ⬇

Coherent SR ⬇

$N_e \sim 10^{10}$

$$P(\lambda) = P_0(\lambda)\left[N_e + N_e(1+N_e)F(\lambda)\right]$$

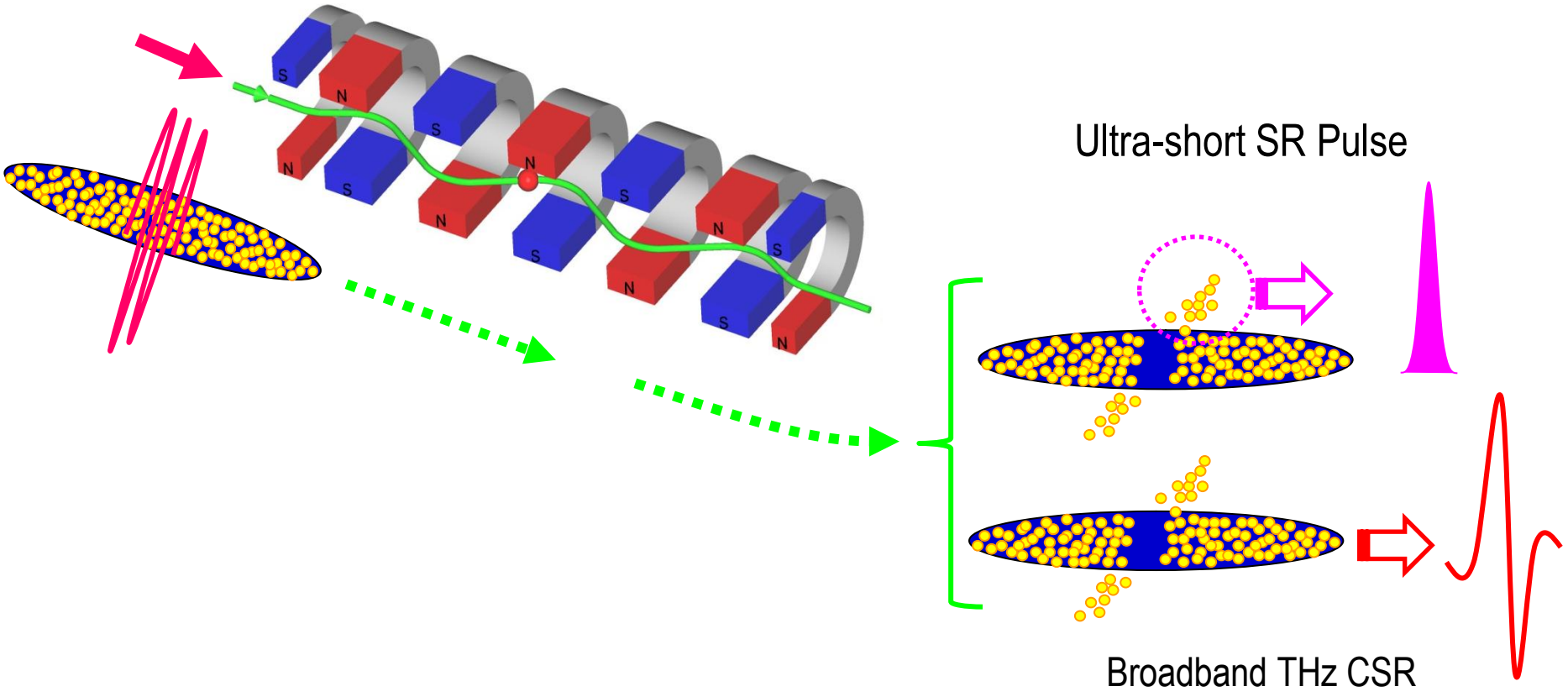
$$F(\lambda) = \left(\int \cos(2\pi z/\lambda) S(z) dz\right)^2$$

$P_0(\lambda)$; SR power from single electron
N_e; Number of electrons in a bunch
$F(\lambda)$; Form factor of electron bunch
$S(z)$; Longitudinal density distribution of electron bunch

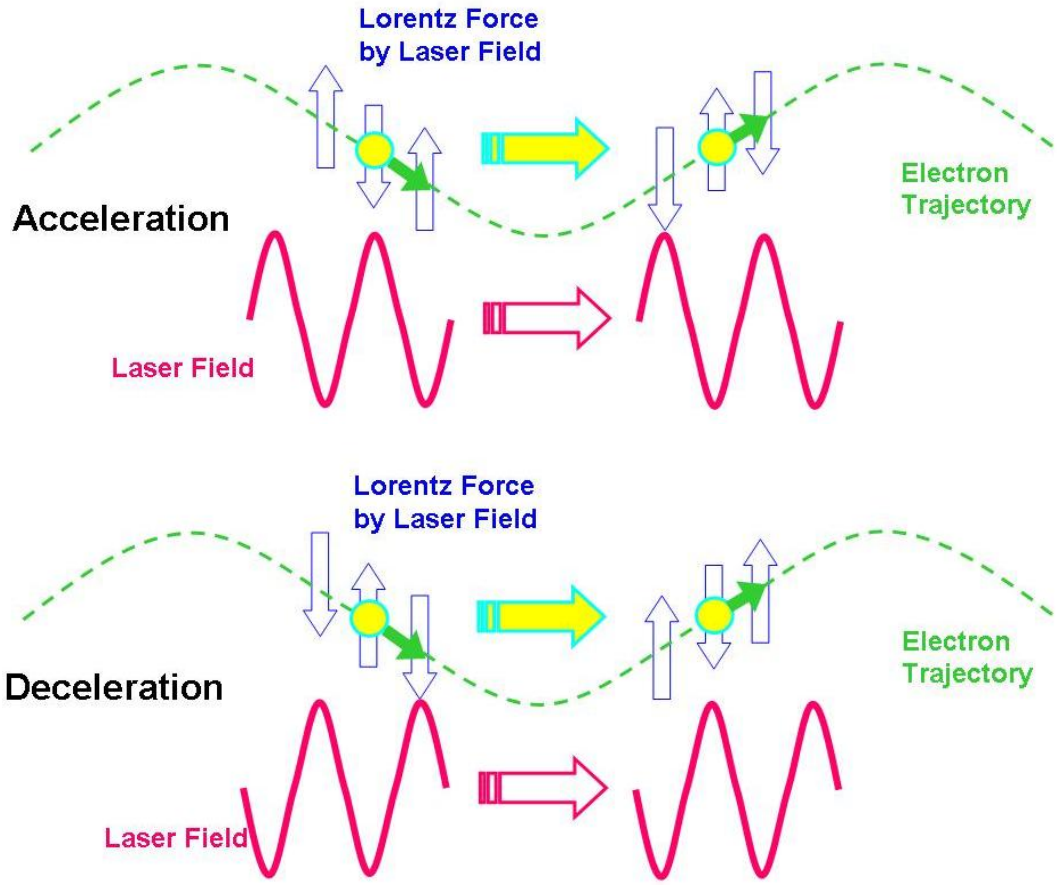
A long e-bunch can radiate coherently when its form factor has non-zero value at the wavelength.

Laser Bunch Slicing

A.A. Zholents, M.S. Zolotorev: Phys. Rev. Lett. 76, 912 (1996)

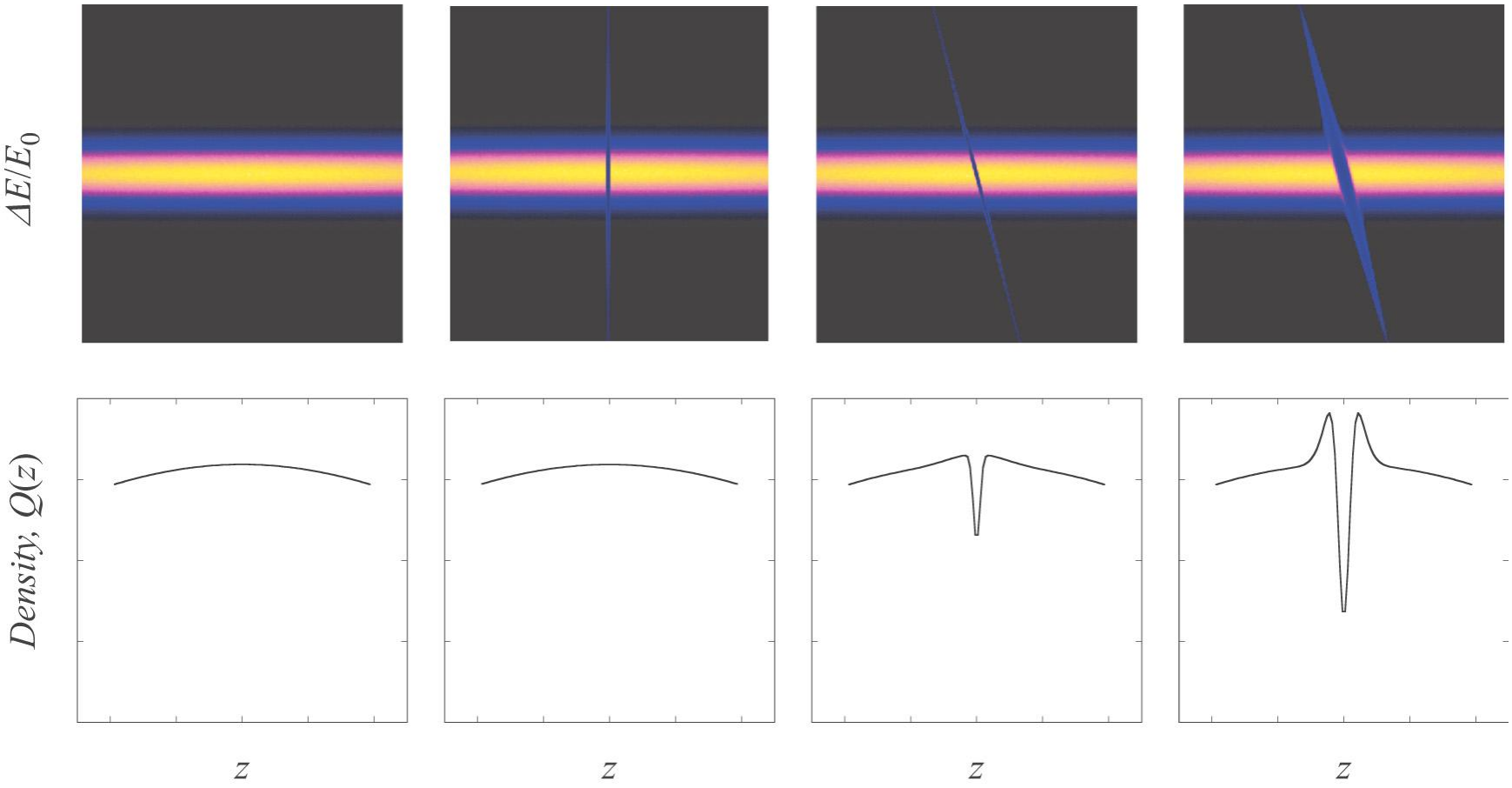


Laser-Electron Interaction in Undulator



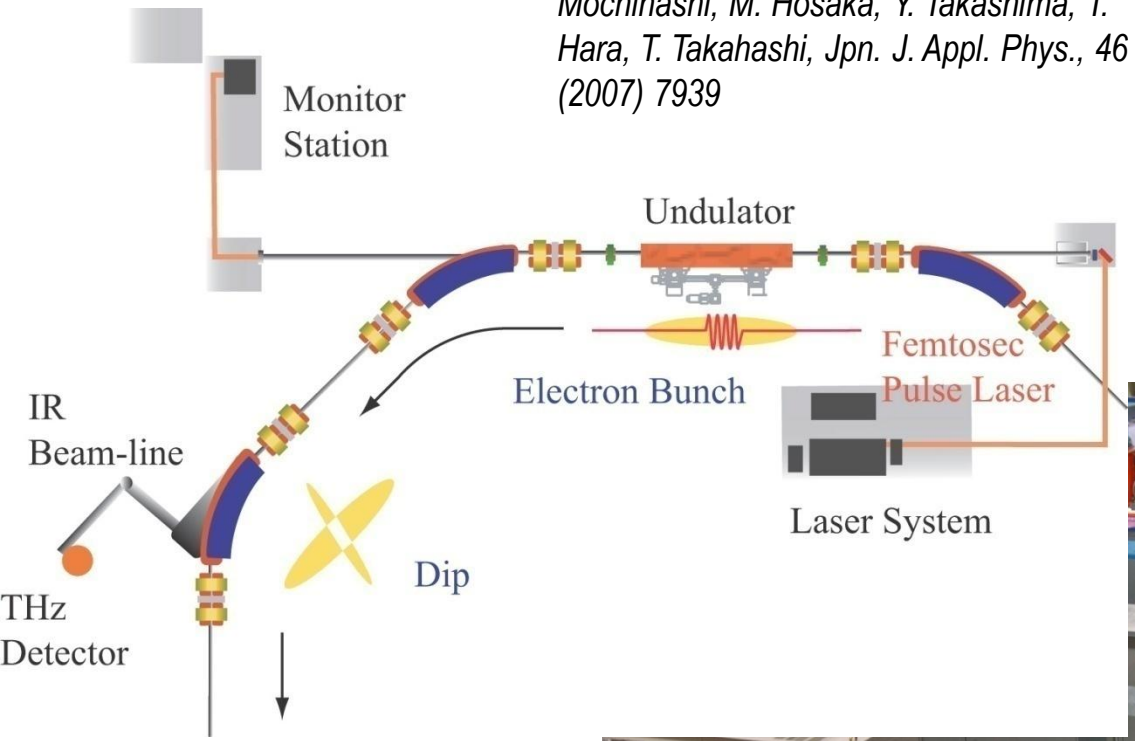
$$\lambda_l = \frac{\left(1 + K^2/2\right)}{2\gamma^2}\lambda_u$$

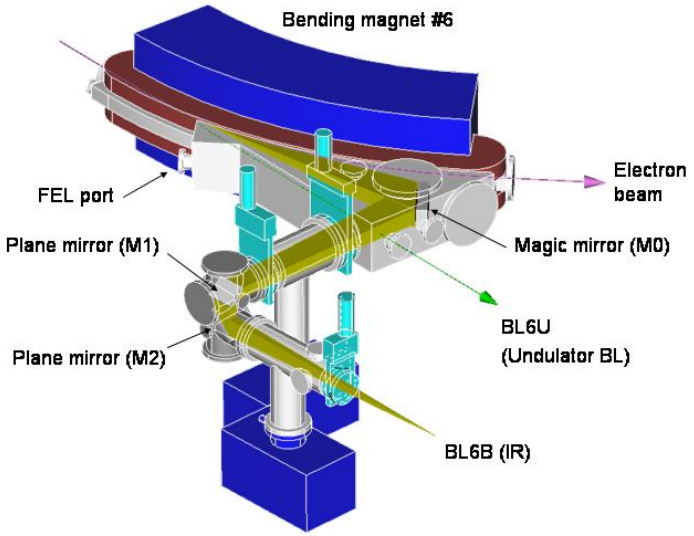
Formation of Dip Structure

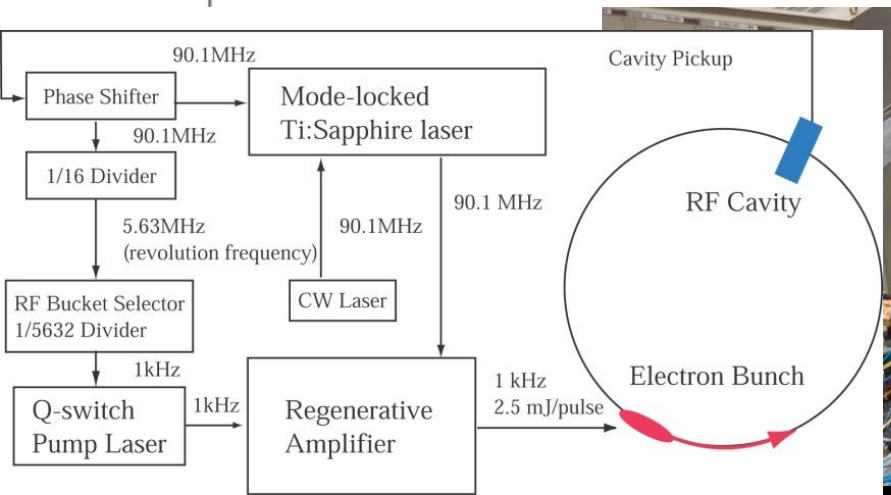


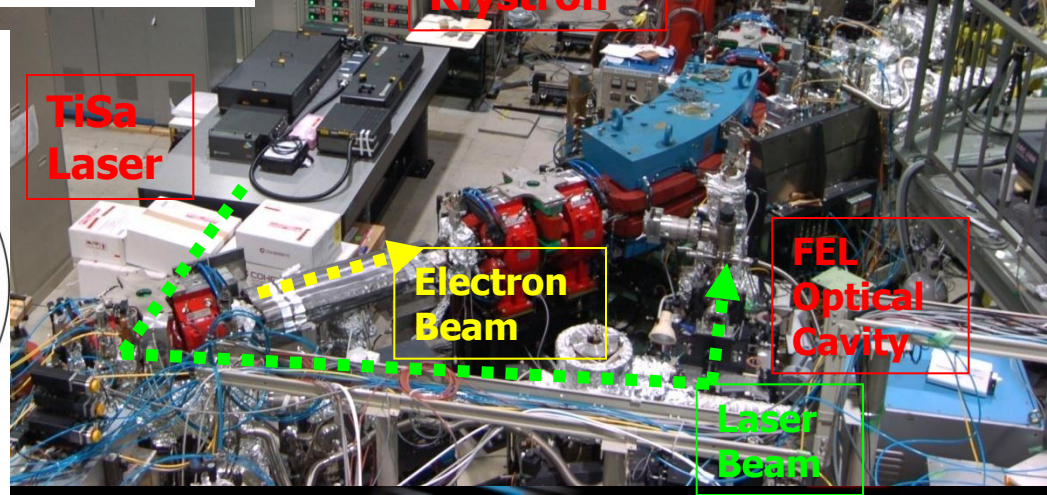
Laser Injection System at UVSOR-II

M. Shimada, M. Katoh, S. Kimura, A. Mochihashi, M. Hosaka, Y. Takashima, T. Hara, T. Takahashi, Jpn. J. Appl. Phys., 46 (2007) 7939









Main Parameters

Storage Ring

Beam Energy	600 MeV
Beam Current	<100 mA (Single Bunch)
Bunch Length	161 ps
Natural Emittance	17.5 nm-rad
Natural Energy Spread	3.4×10^{-4}
Revolution Frequency	5.64 MHz

Laser

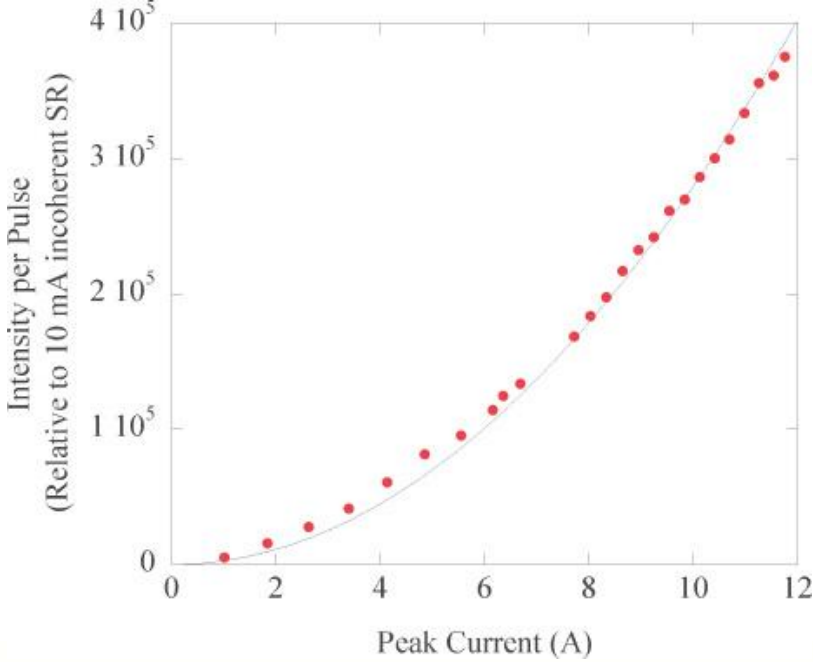
Wavelength	800 nm
Pulse Energy	2.5 mJ
Pulse Duration	130 fs – 300 psec
Repetition Rate	1 kHz

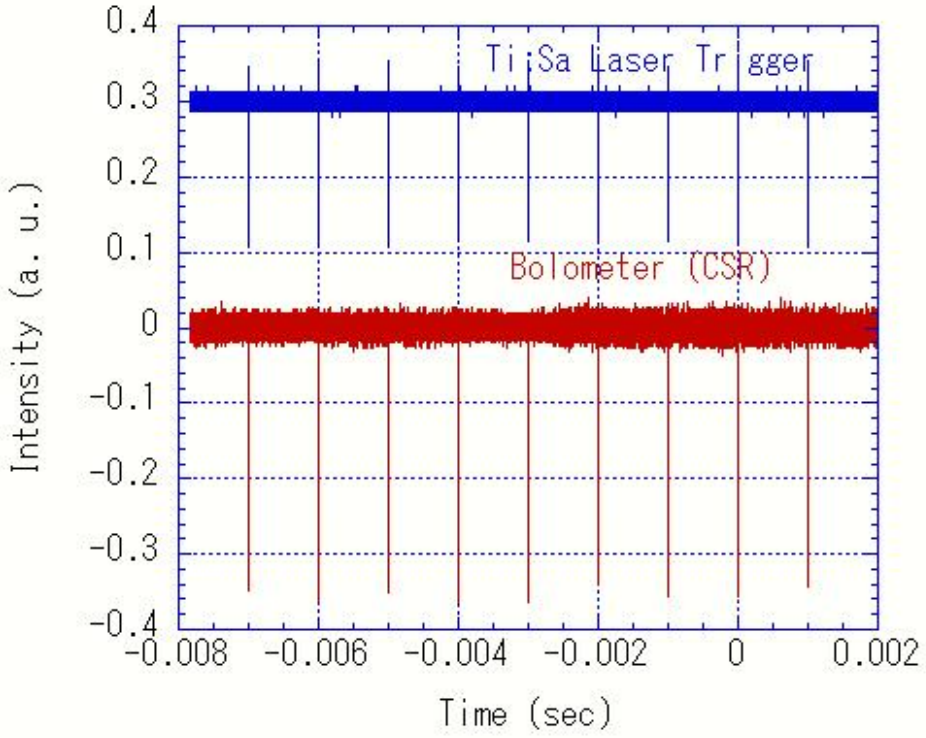
Optical Klystron

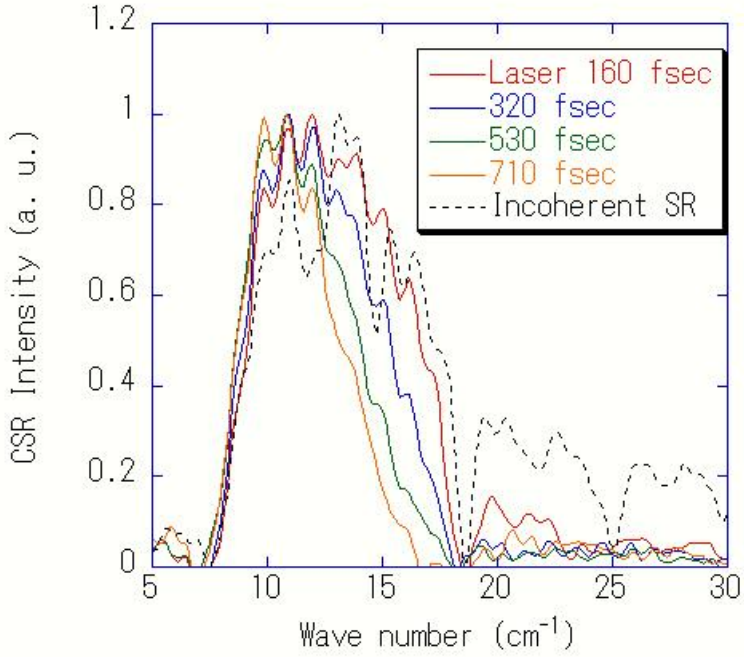
Period Length	110 mm
Number of Periods	9 + 9
K Value	6.18
N_d	45

Terahertz CSR by Laser Slicing at UVSOR-II

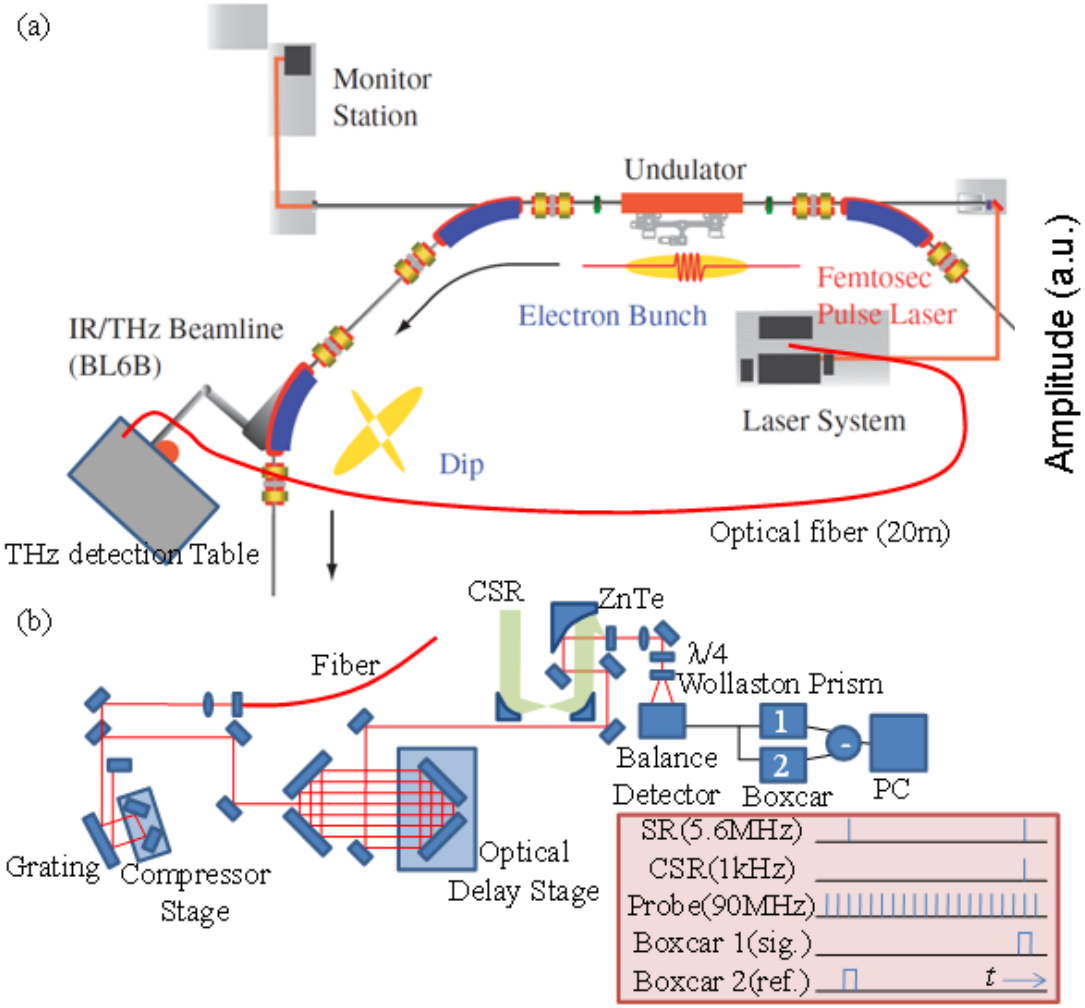
M. Shimada, M. Katoh, S. Kimura, A. Mochihashi, M. Hosaka, Y. Takashima, T. Hara, T. Takahashi,
Jpn. J. Appl. Phys., 46 (2007) 7939

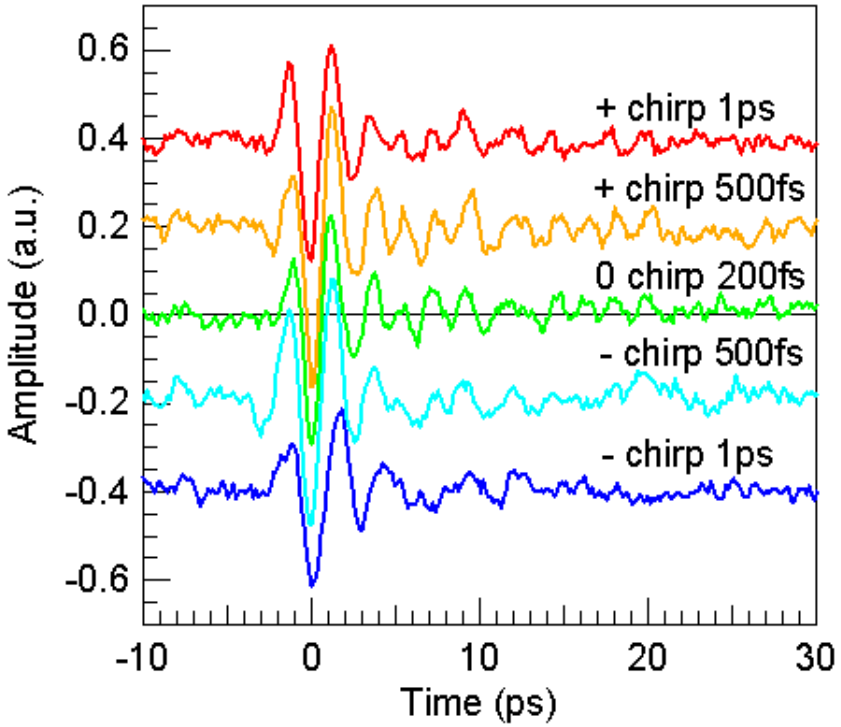






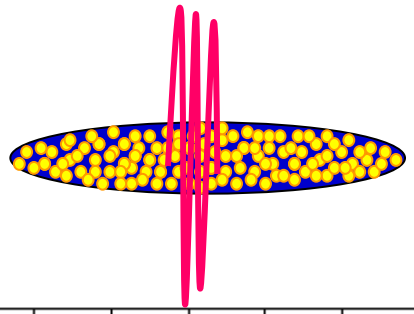
THz CSR Field Detection by EO Sampling Method at UVSOR-II

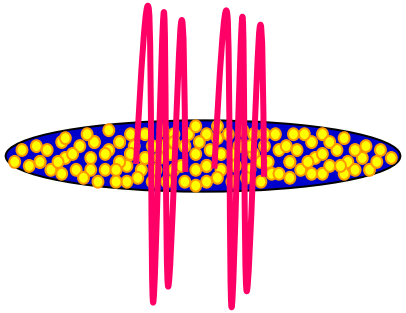


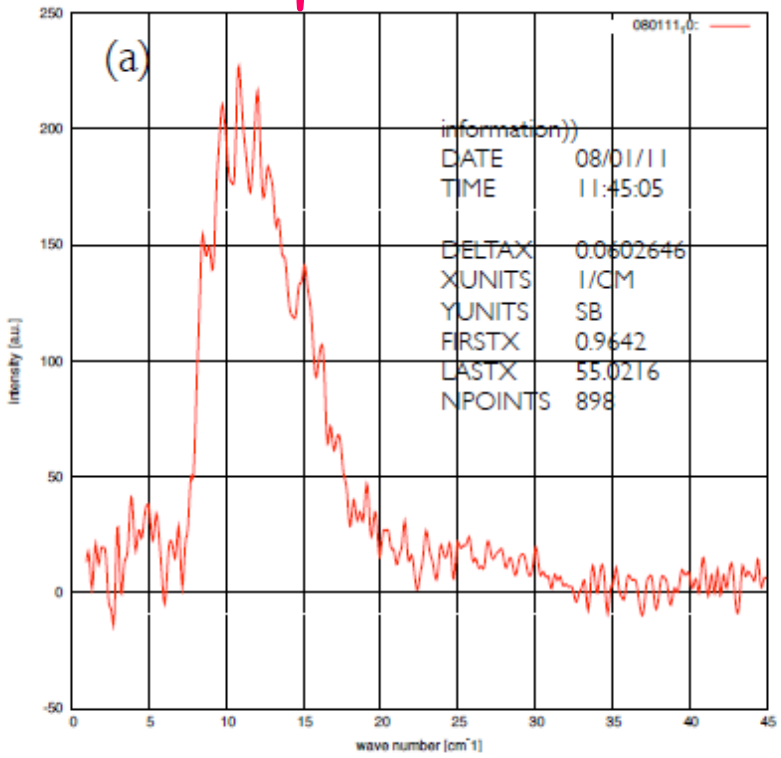


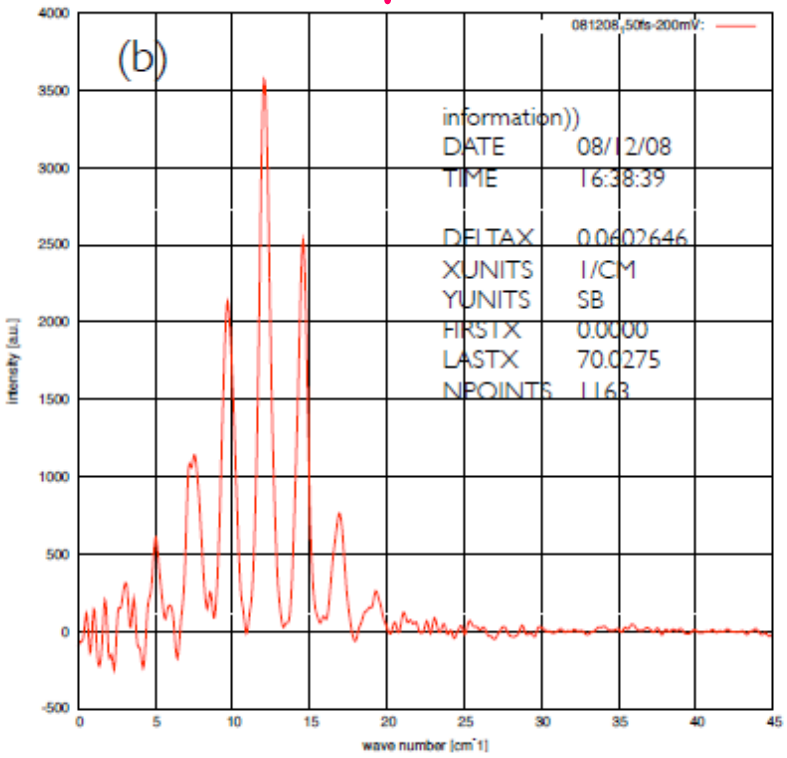
I. Katayama, H. Shimosato, M. Bito, K. Furusawa, M. Adachi, M. Shimada, H. Zen, S. Kimura, N. Yamamoto, M. Hosaka, M. Katoh, M. Ashida, presented at 2010 CLEO/QELS (2010)

THz CSR by Double Pulse Injection (by accident) at UVSOR-II



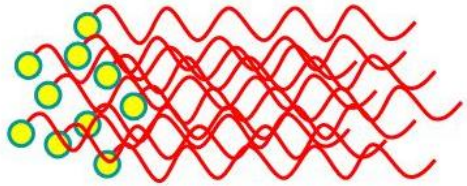




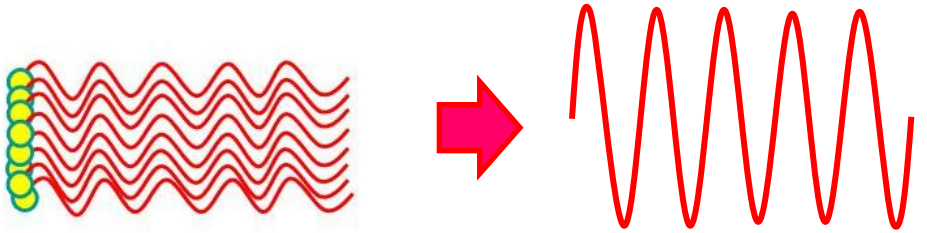


Coherent Synchrotron Radiation from Micro-bunched e-Beam

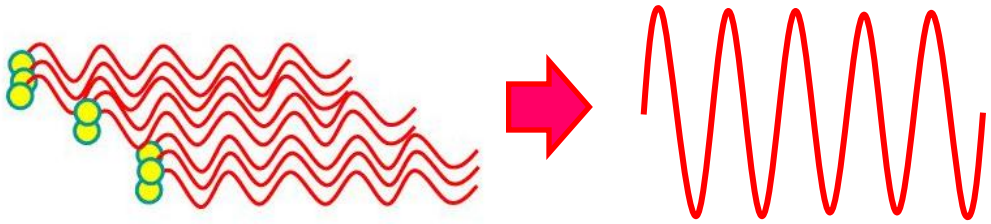
Normal Synchrotron Radiation



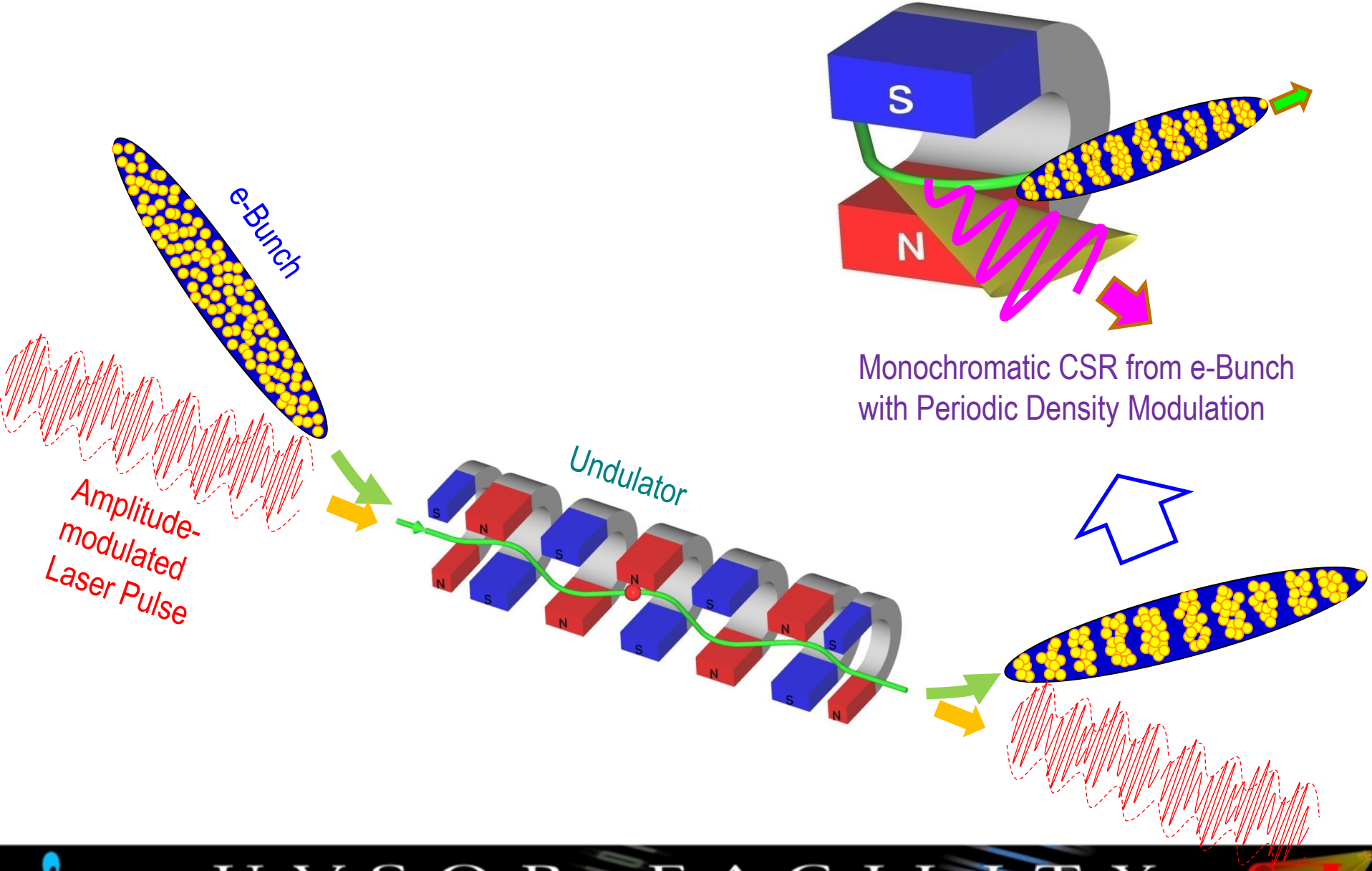
Coherent Synchrotron Radiation from Ultra-short e-Bunch



Coherent Synchrotron Radiation from Micro-bunched e-Bunch

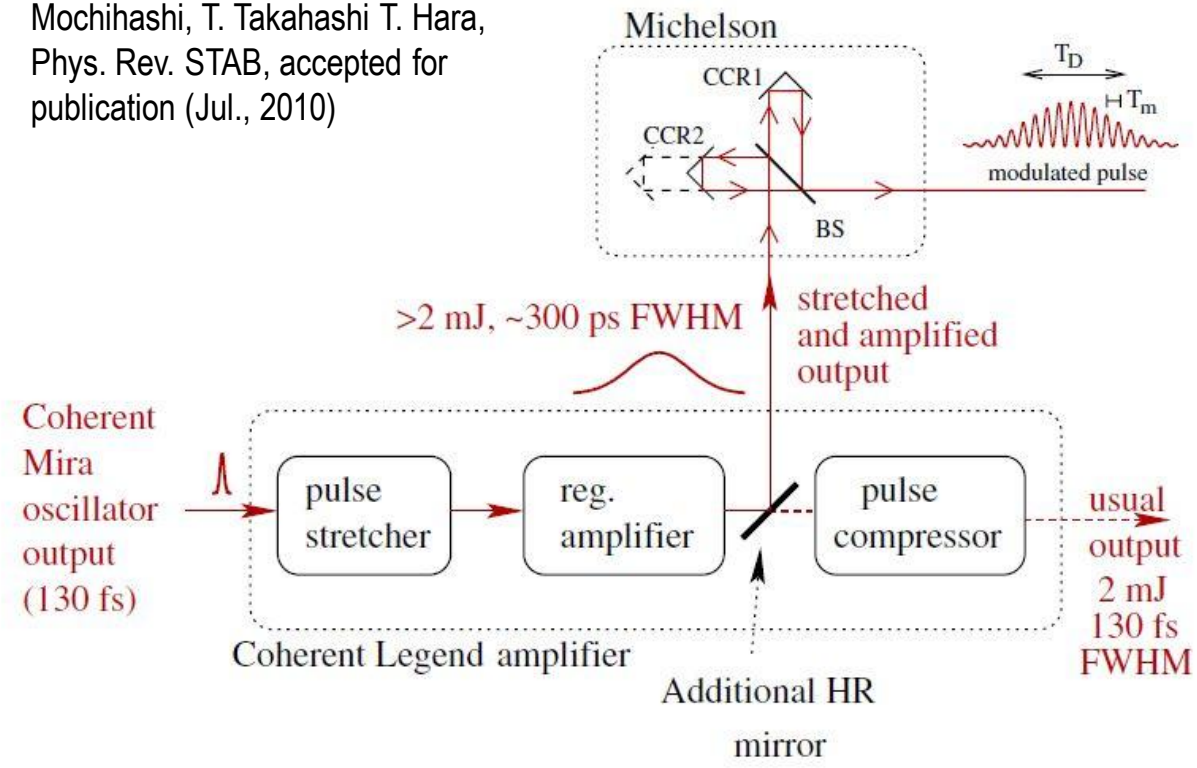


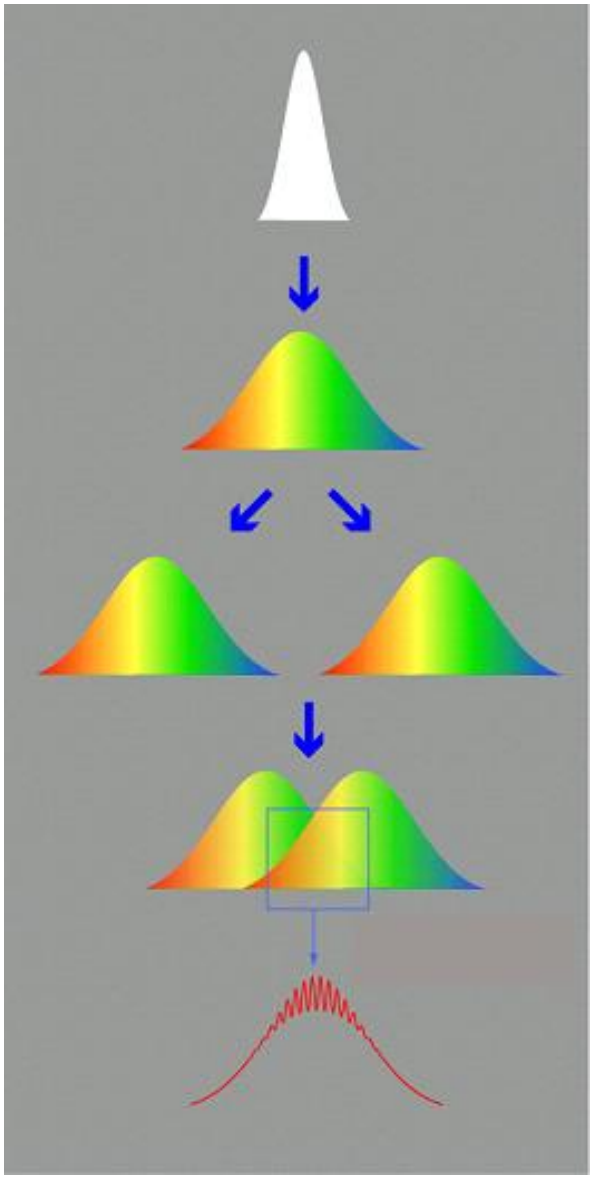
CSR from Laser-modulated e-Bunch



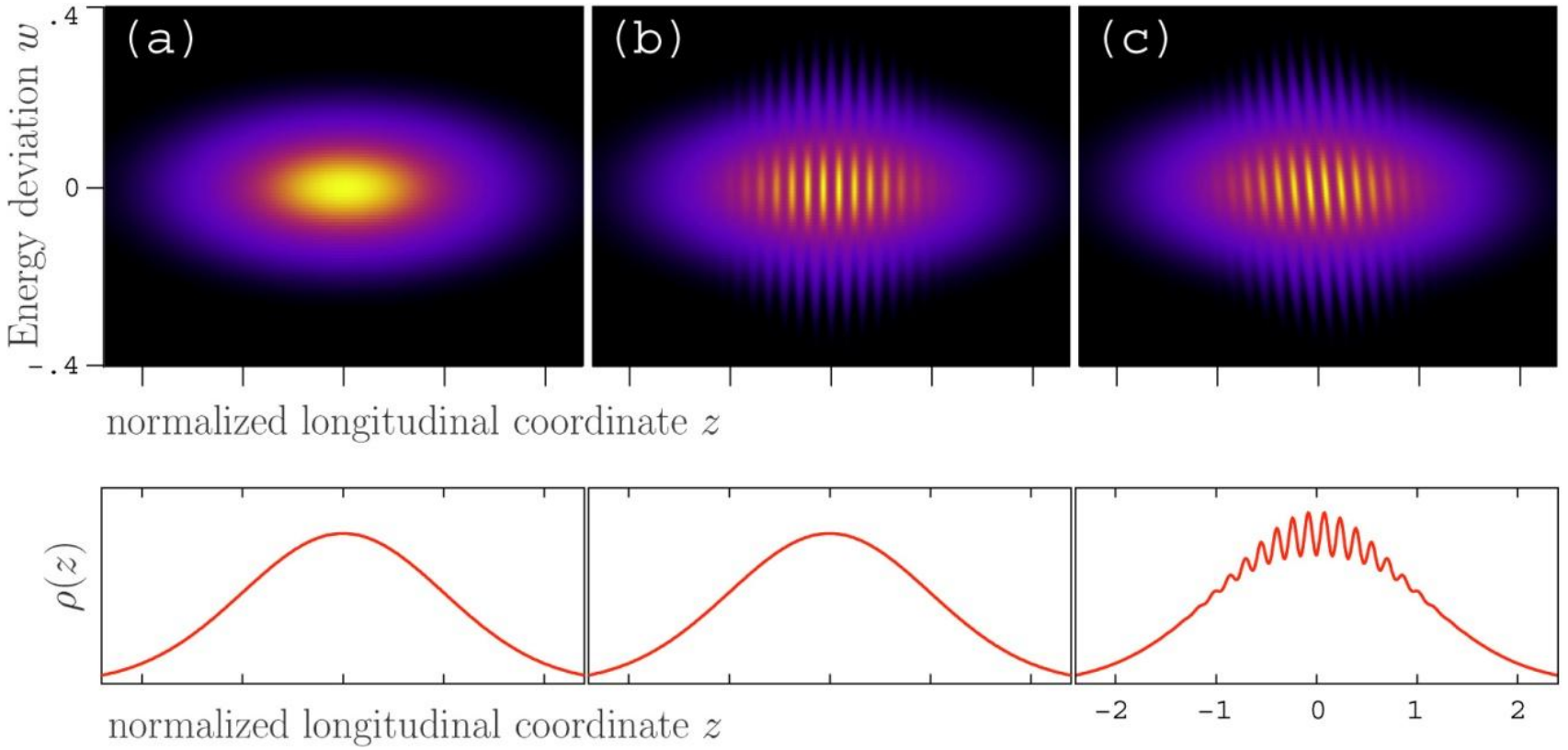
Amplitude-modulated Laser Pulse by Chirped Pulse Beating at UVSOR-II

C. Evain, C. Szwaj, S. Bielawski, M. Hosaka, Y. Takashima, M. Shimada, S. Kimura, M. Katoh, A. Mochihashi, T. Takahashi T. Hara, Phys. Rev. STAB, accepted for publication (Jul., 2010)





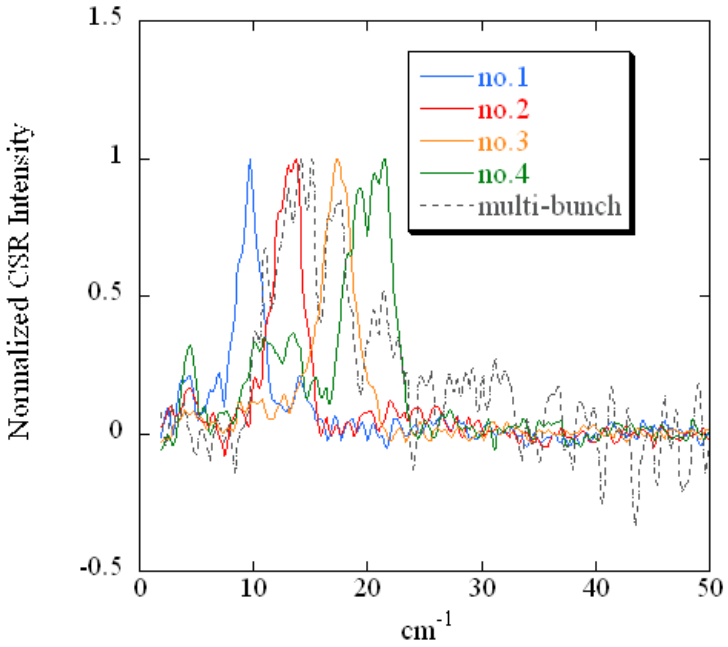
Formation of Periodic Micro-structure

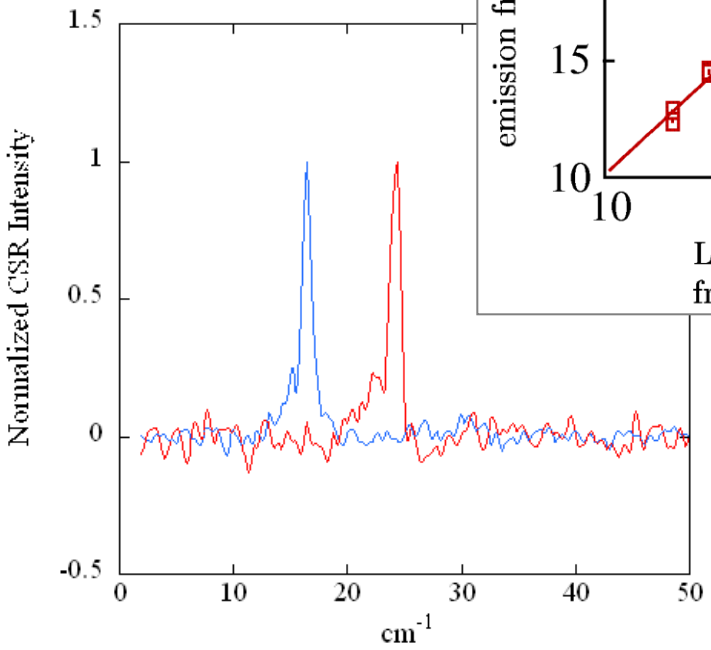


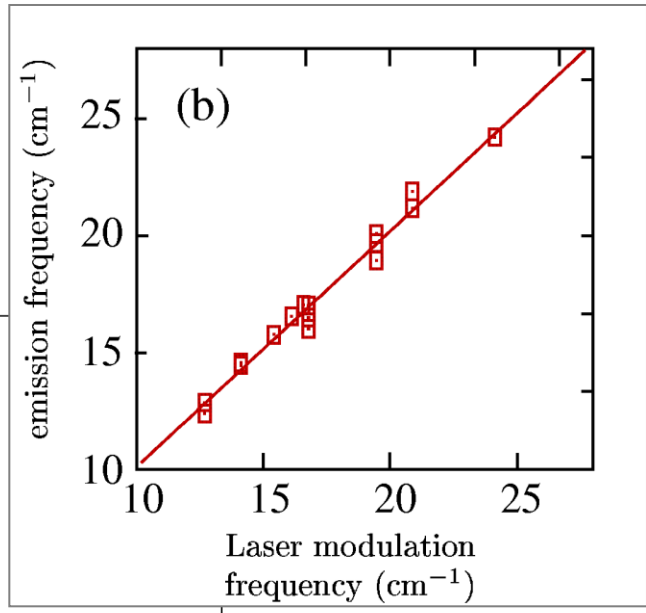
Monochromatic & Tunable THz CSR from Bending Magnet at UVSOR-II

not from Undulator !

S. Bielawski, C. Evain, T. Hara, M. Hosaka, M. Katoh, S. Kimura, A. Mochihashi, M. Shimada, C. Szwaj, T. Takahashi, Y. Takashima, Nature Physics, 4 (2008), 390-393



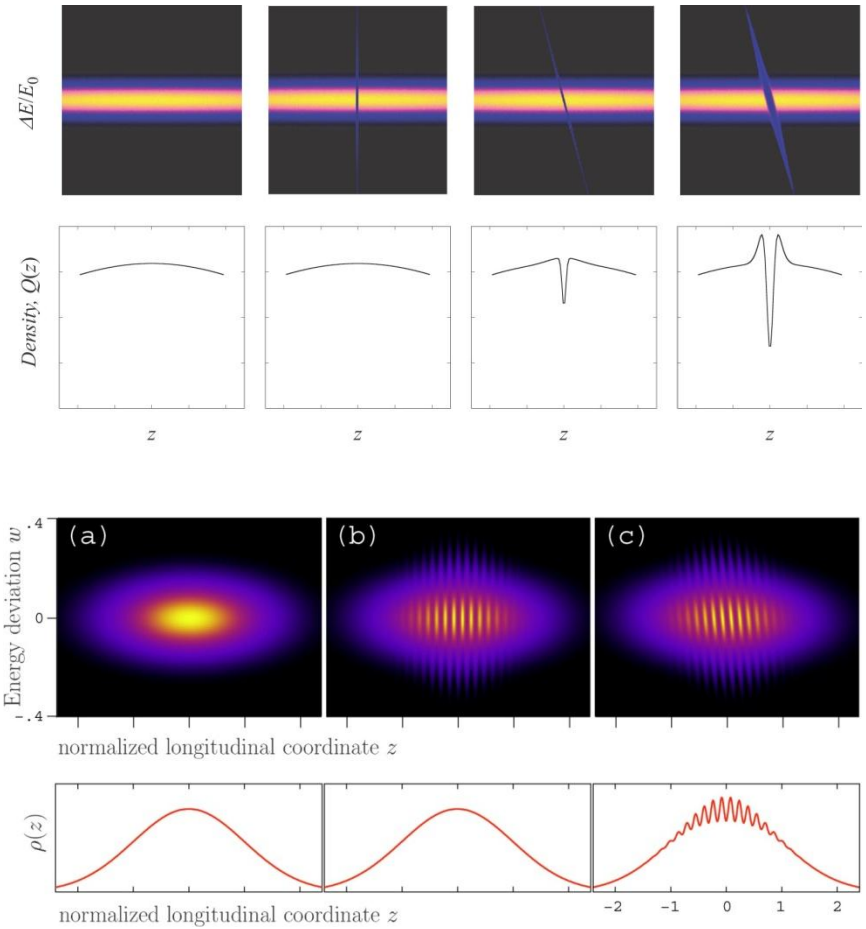


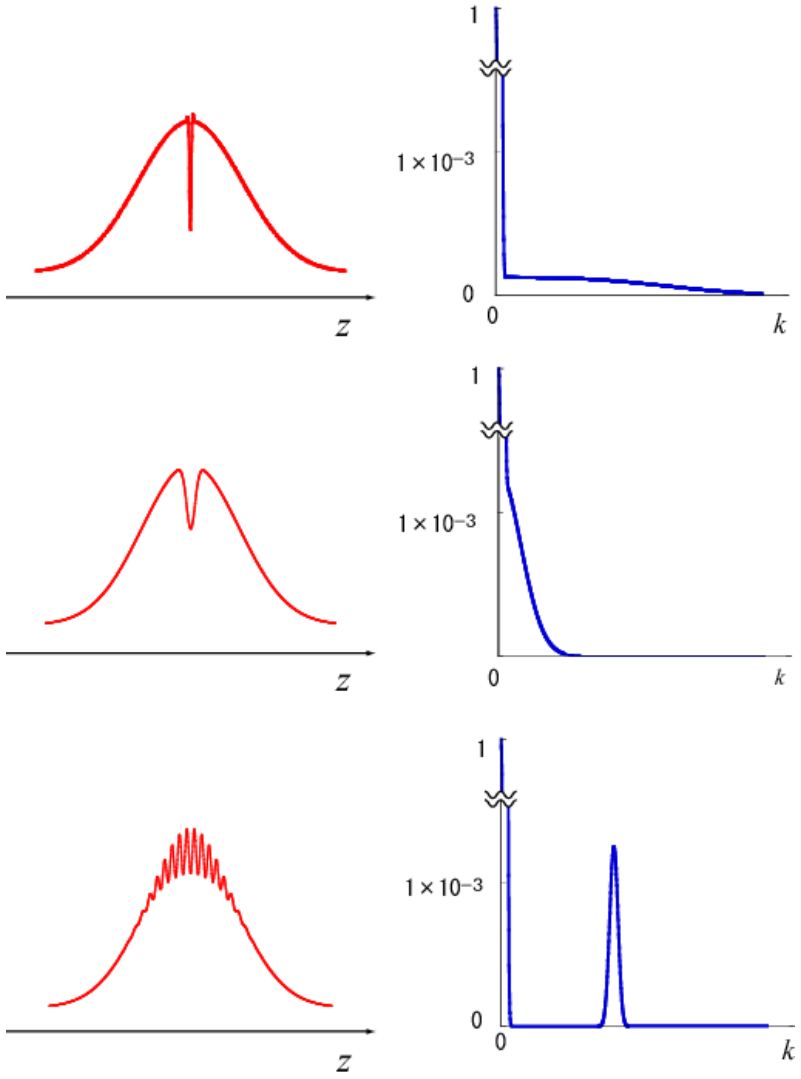


Less beats with shorter pulse duration (~ 2ps)

More beats with longer pulse duration (~ 60ps)

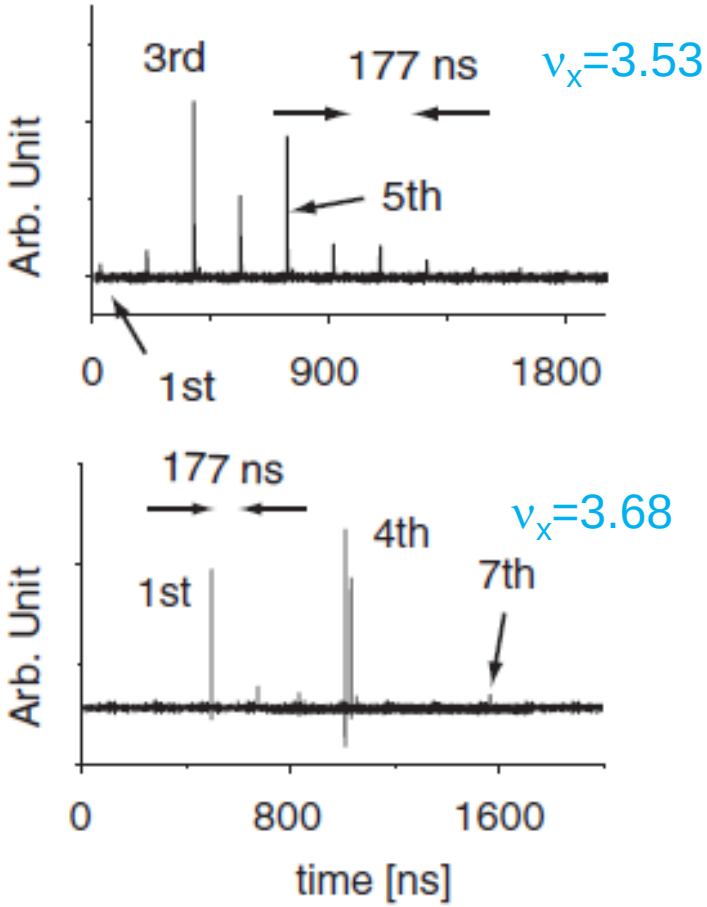
Broadband and Narrowband THz CSR

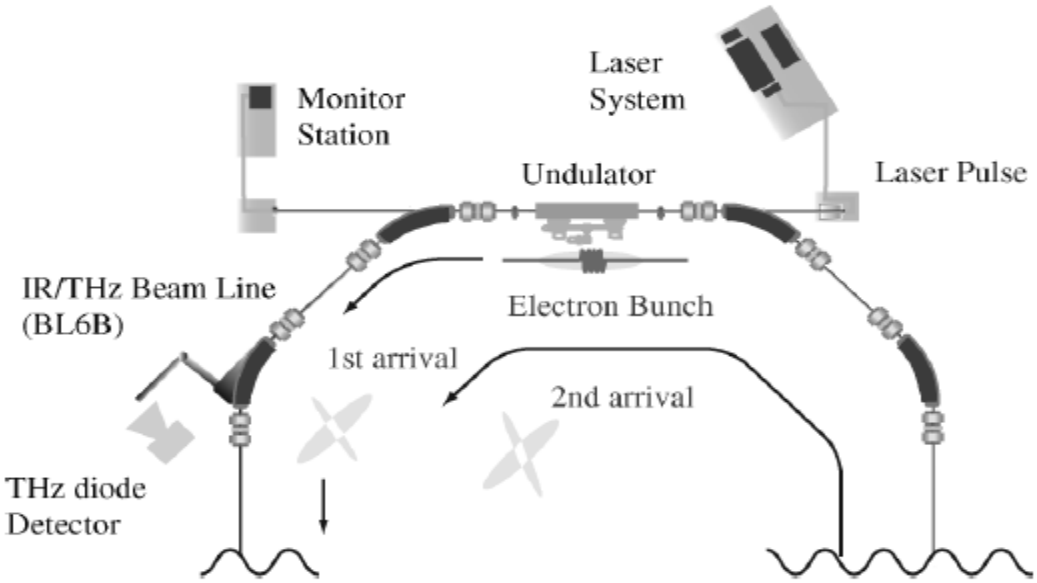




Turn-by-turn Measurement of THz CSR by Laser Slicing at UVSOR -II

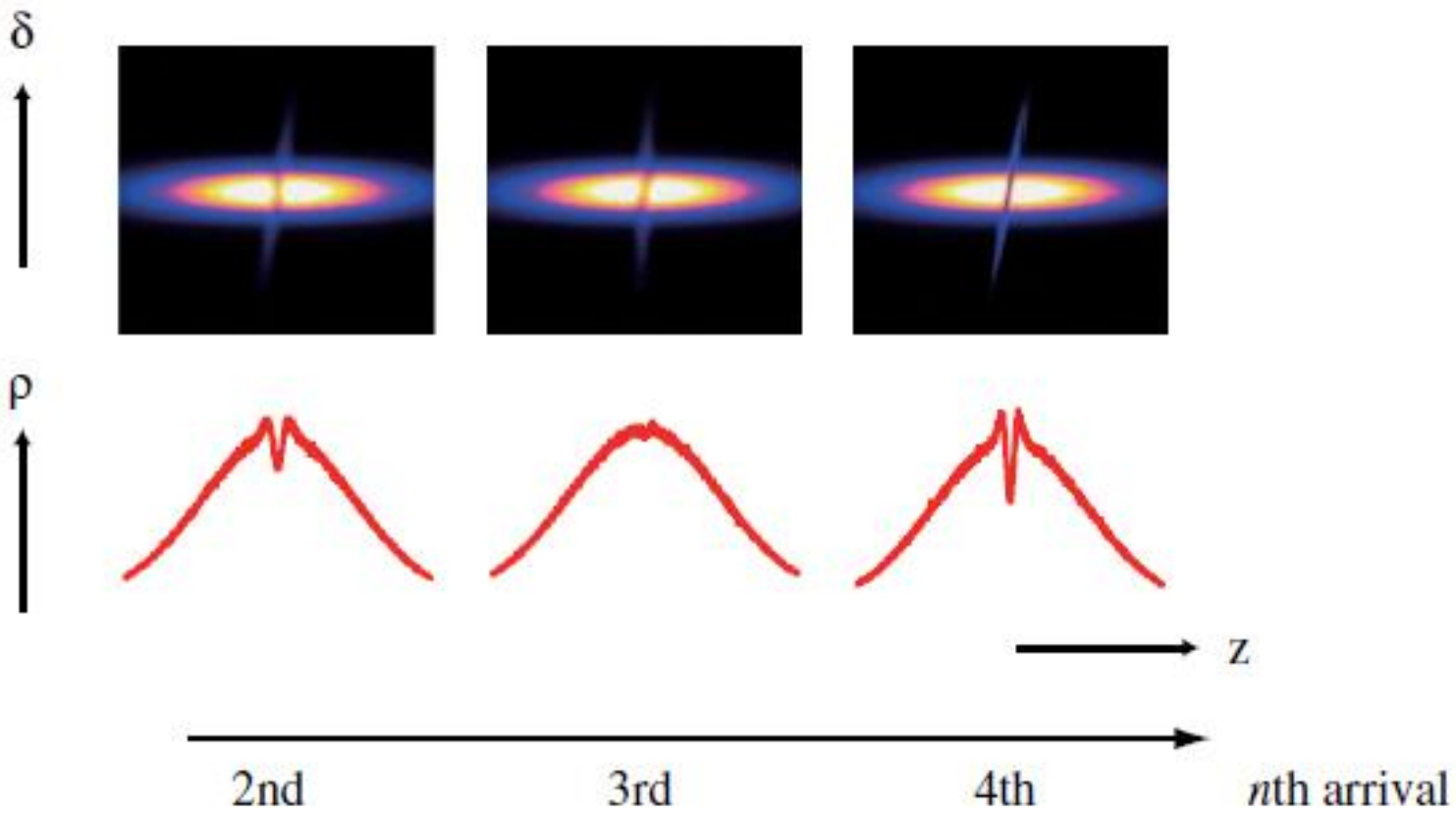
M. Shimada, M. Katoh, M. Adachi, T. Tanikawa, S. Kimura, M. Hosaka, N. Yamamoto, Y. Takashima, T. Takahashi, Phys. Rev. Lett. 103, 144802 (2009)



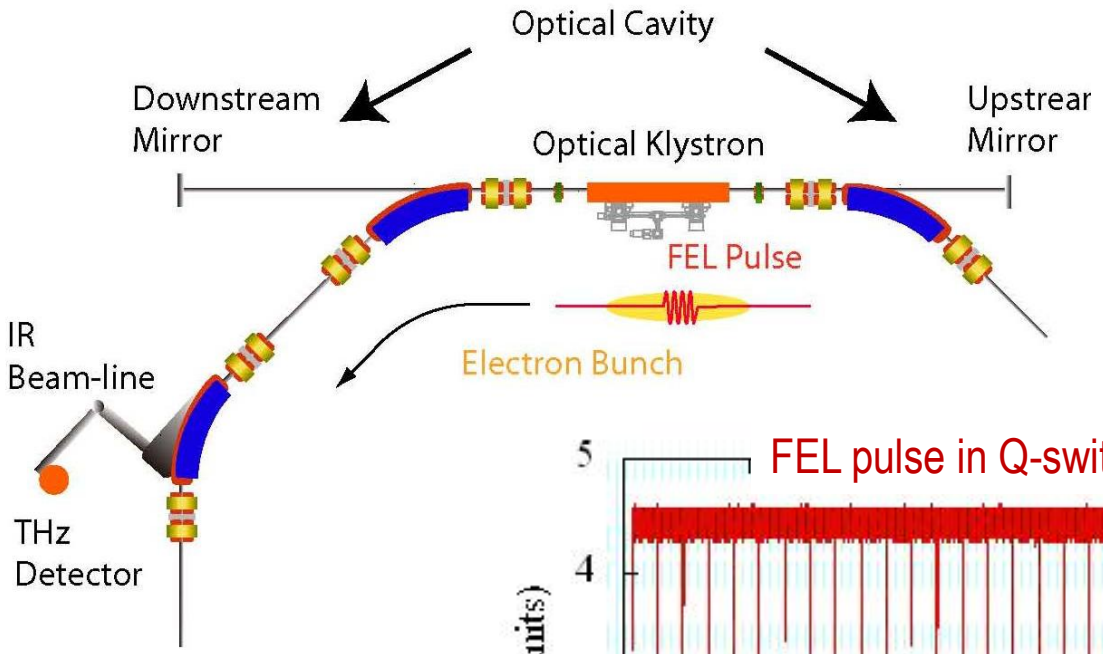


Longitudinal-Transverse Coupling in Laser Slicing

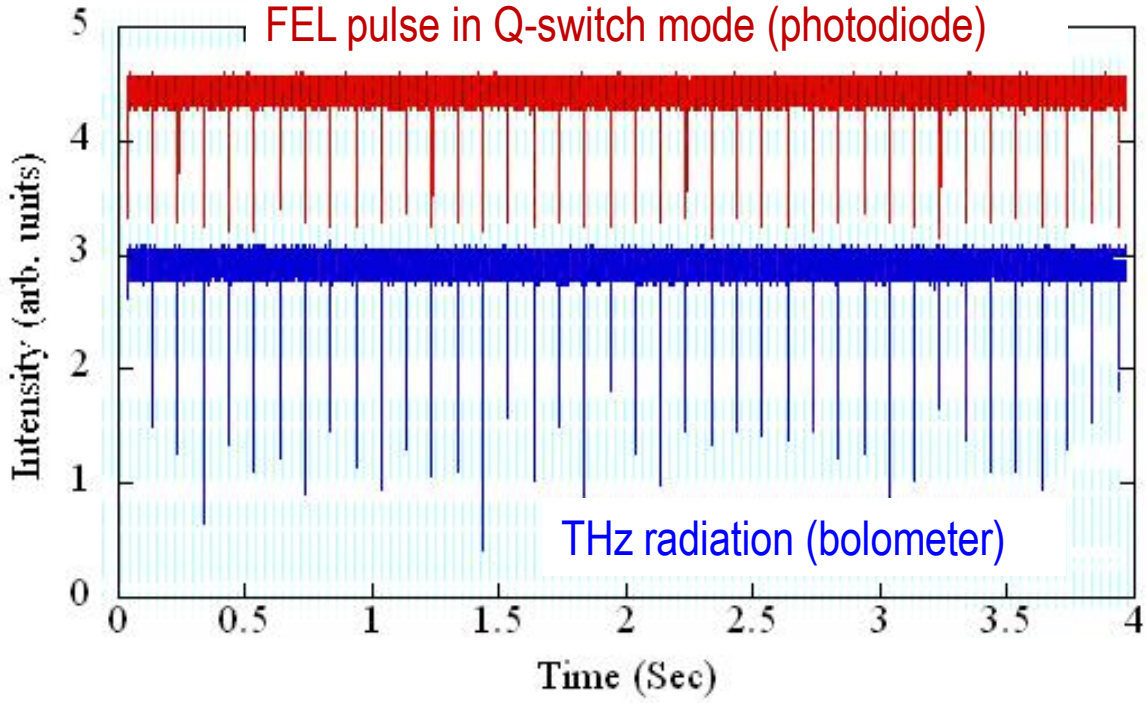
M. Shimada, M. Katoh, M. Adachi, T. Tanikawa, S. Kimura, M. Hosaka, N. Yamamoto, Y. Takashima, T. Takahashi, Phys. Rev. Lett. 103, 144802 (2009)



CSR Emission during FEL Oscillation in Q-switching mode at UVSOR-II



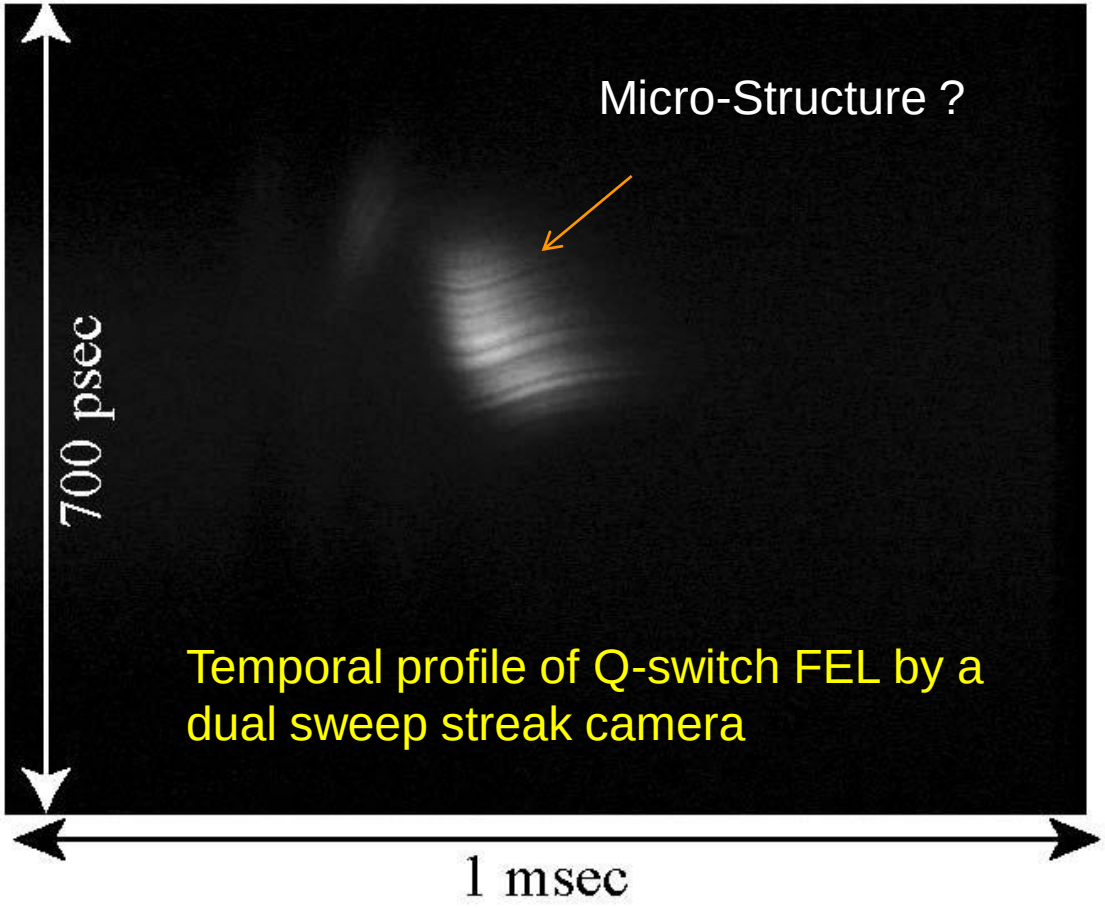
M. Hosaka, Y. Takashima, A. Mochihashi, M. Shimada, T. Takahashi, M. Katoh, S. Kimura, presented at FEL2008 (Gyeongju, 2008)



E = 600 MeV
λ= 520 nm
Q-switch :
RF modulation
with Repetition 10Hz

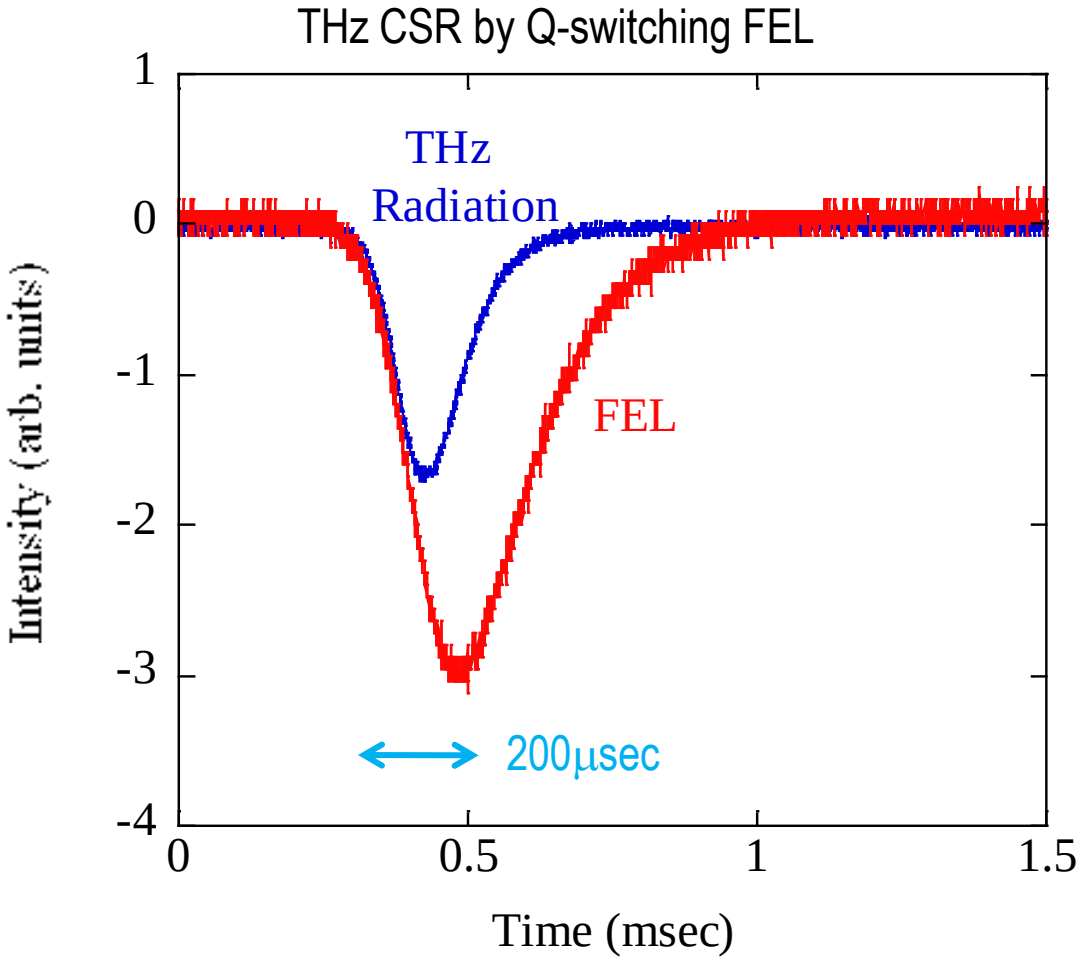
CSR Emission during FEL Oscillation in Q-switching mode at UVSOR-II(cont.)

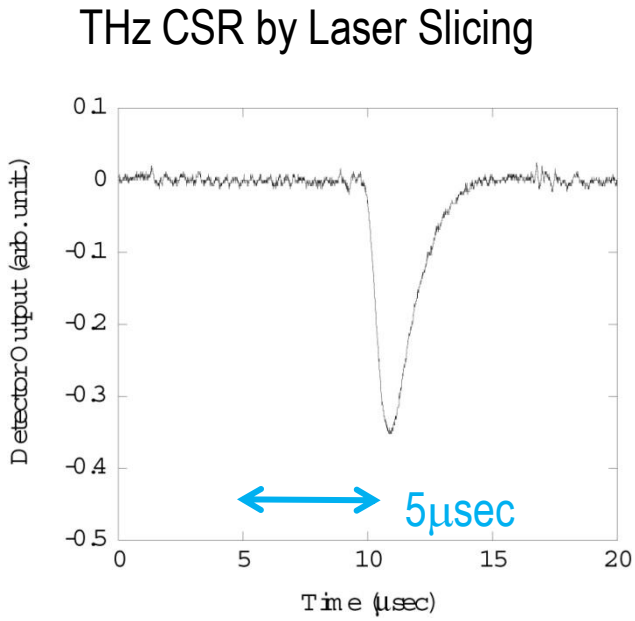
Why THz-CSR by Long (~100 psec) FEL Pulse?



Sub-picosecond Micro-structure in Q-switch FEL Pulse?

CSR Emission during FEL Oscillation in Q-switching mode at UVSOR-II(cont.)





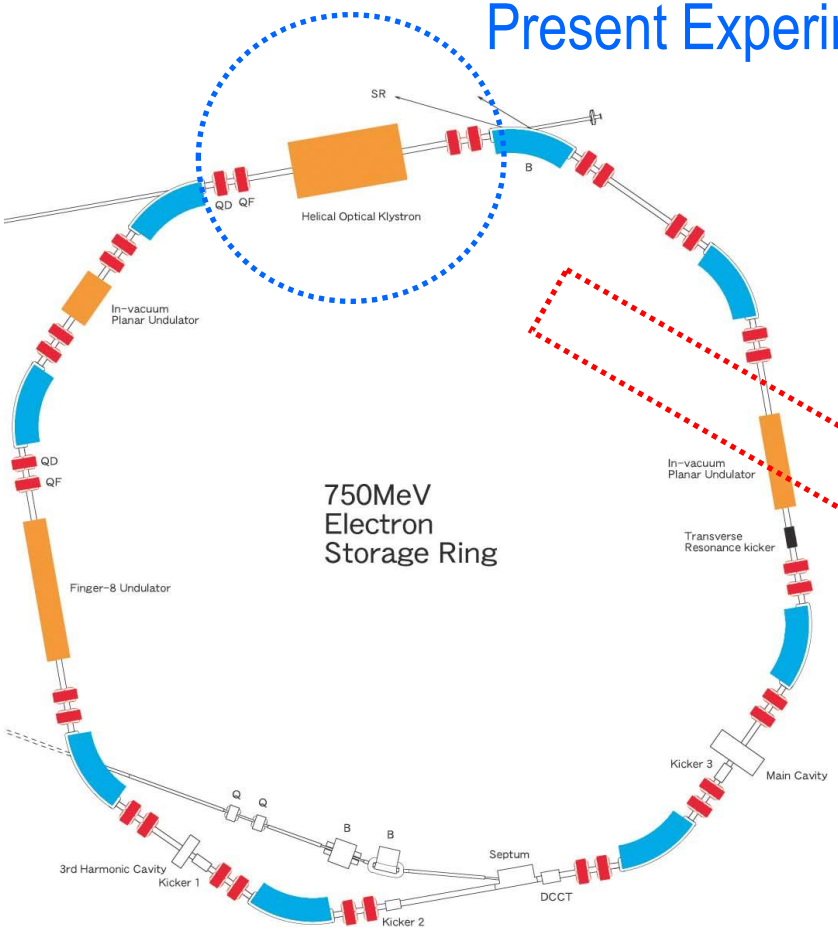
Temporal resolution of bolometer : ~2 μsec (FWHM).

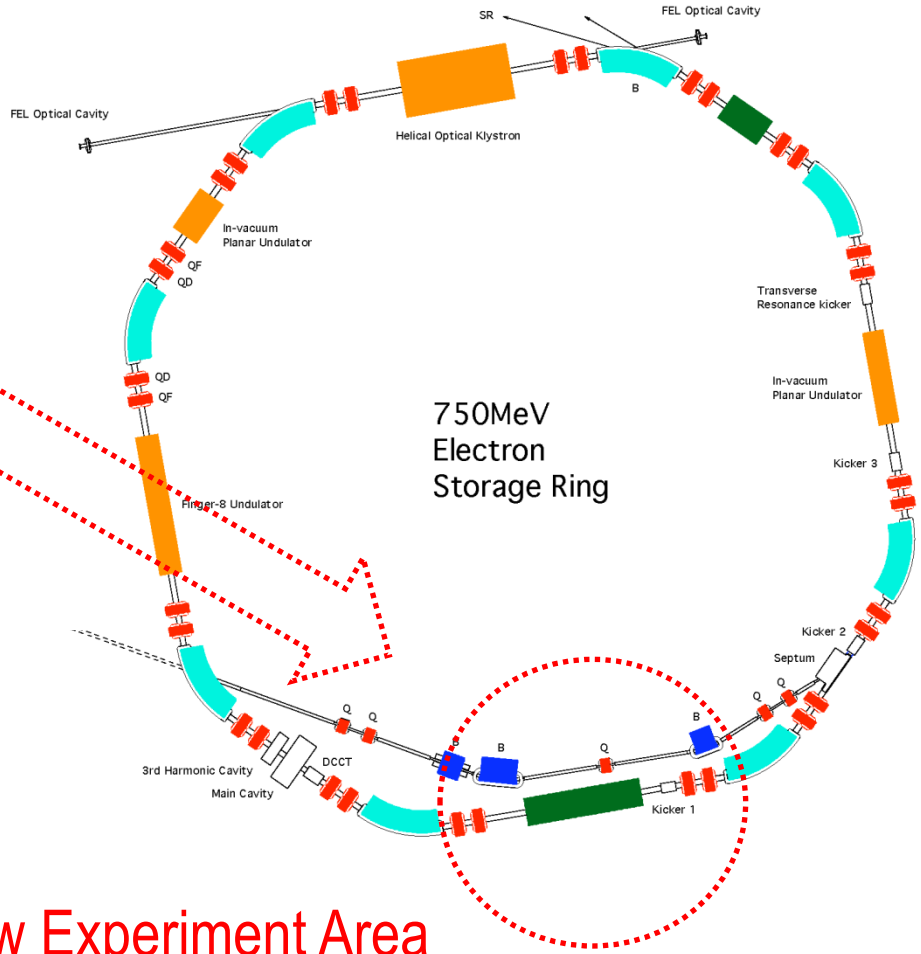
SUMMARY and PROSPECTS

- We can control wavelength, amplitude, phase, bandwidth, number of cycles… of synchrotron radiation by laser modulation technique.
- Possibility to sustain micro-density structure and CSR emission for many revolutions?
- Laser modulation technique on ERL for ultra-high power CSR source?
- Users application using VUV-CHG + THz-CSR?

New Straight Section for Source Development at UVSOR-II

Present Experiment Area

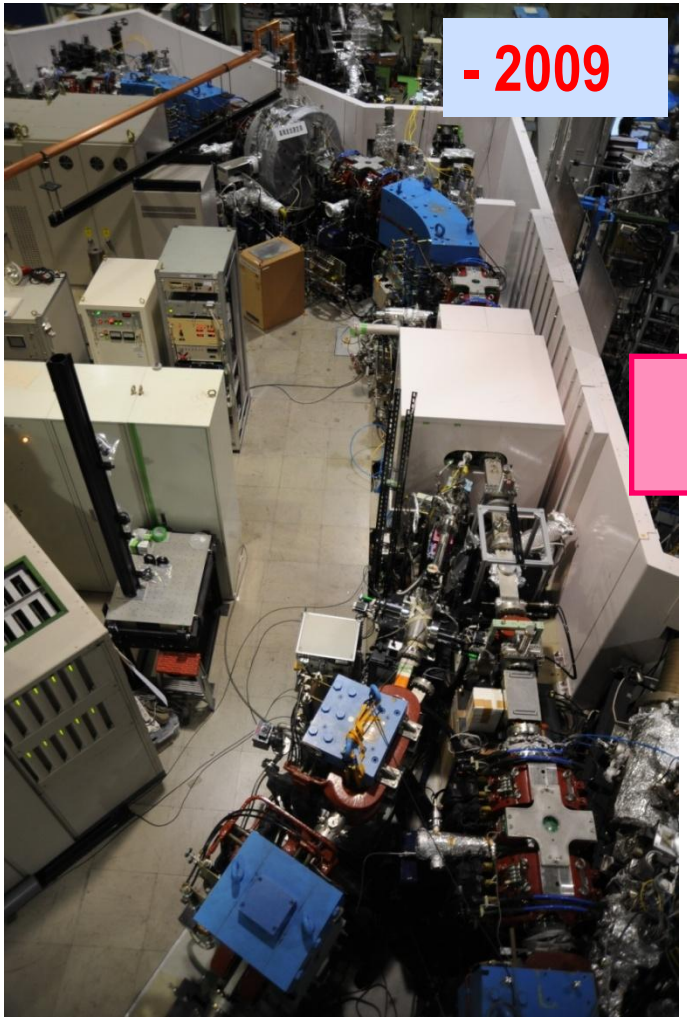


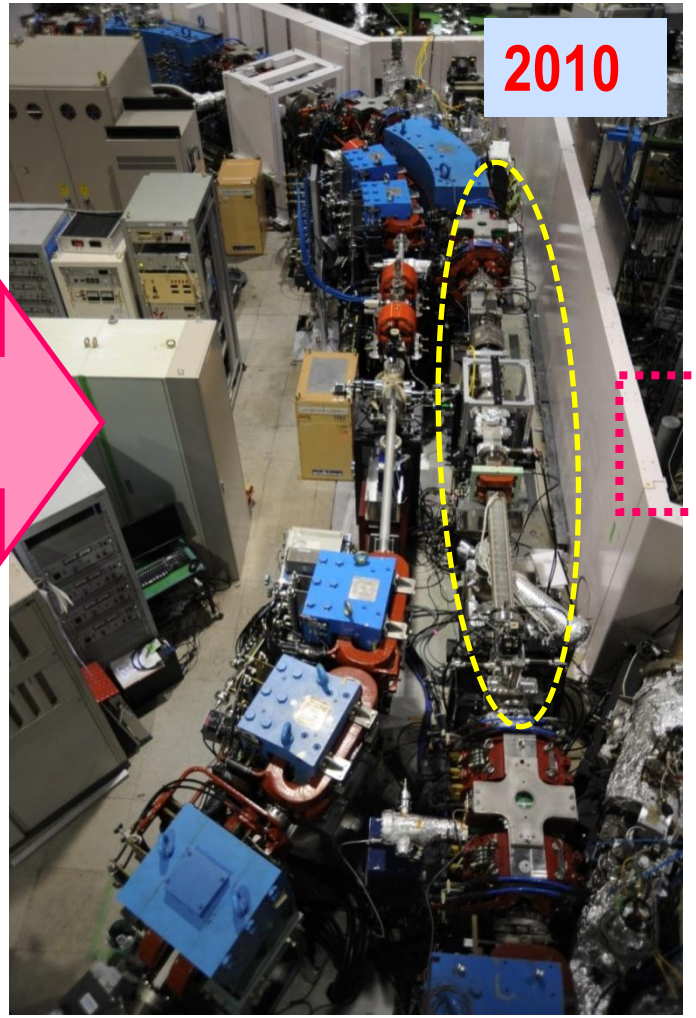


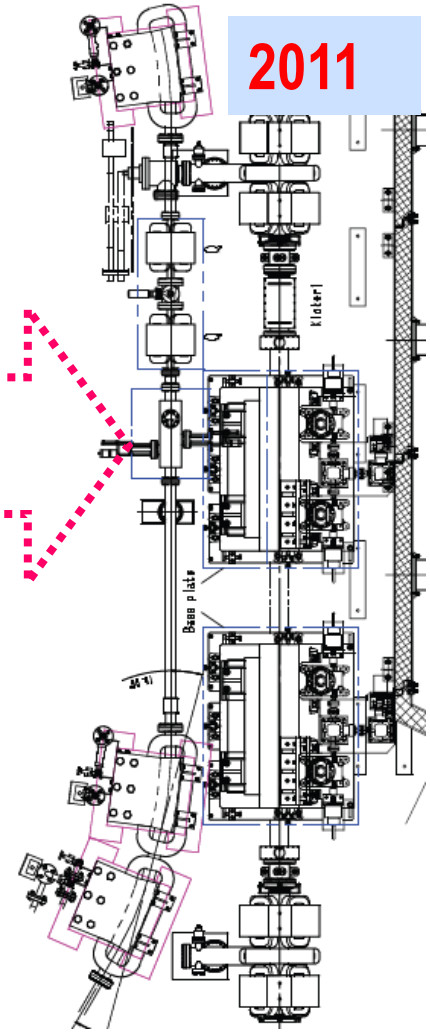
New Experiment Area

New Straight Section for Source Developments

CSR, CHG, FEL, LCγ …







Thank You

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