Generation of THz CSR with laser-bunch slicing in UVSOR-II electron storage ring

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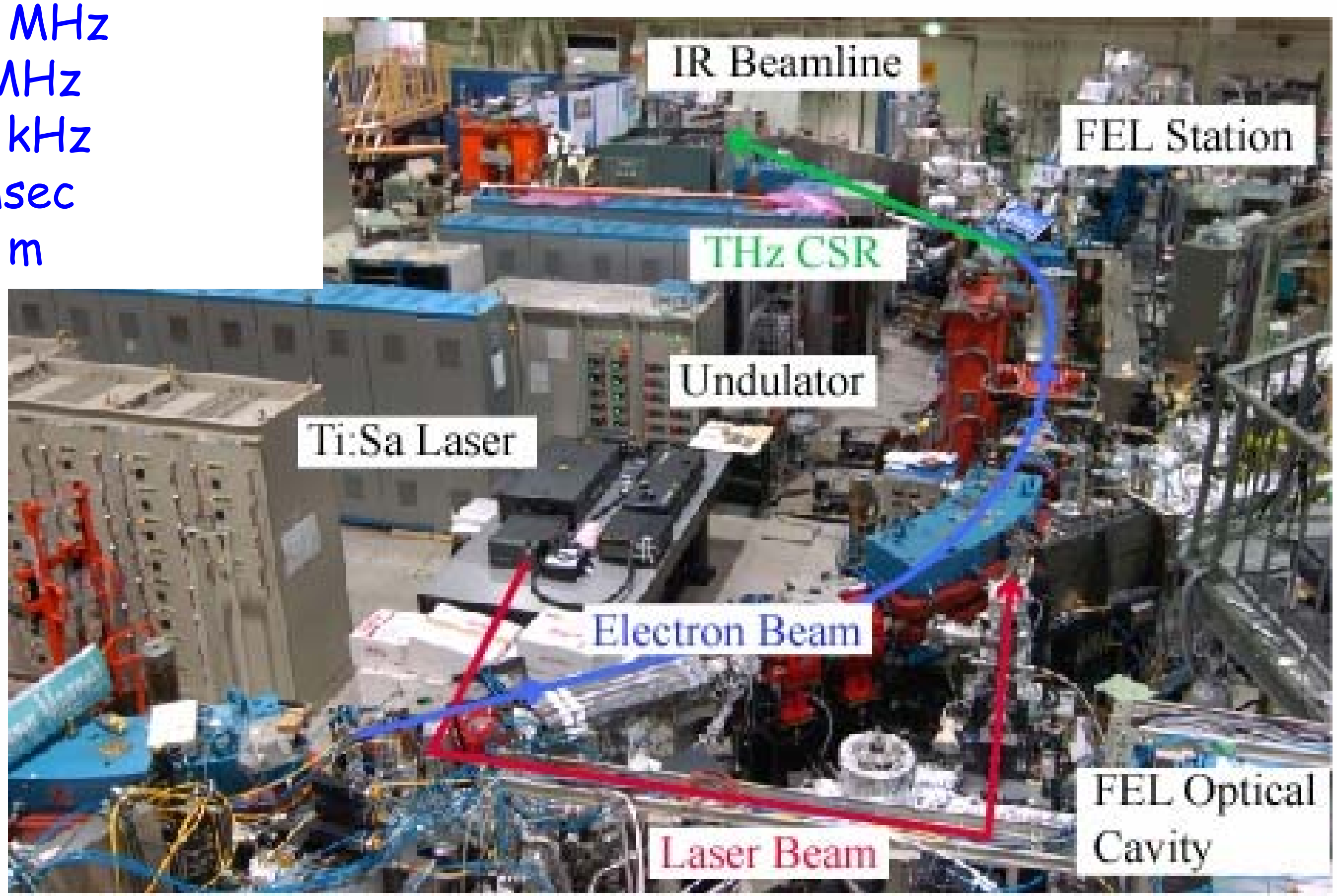
UVSOR-II Electron Storage Ring

Electron Energy	600 MeV
Circumference	53.2 m
Natural Emittance	17.4 nm-rad
Natural Energy Spread	3.4×10^{-4}
Natural Bunch Length	3.1 cm (~100psec)
RF Frequency	90.1 MHz
Revolution Frequency	5.6 MHz
Synchrotron Frequency	14.4 kHz
Damping time	19 msec
Undulator Length	2.31 m



The laser system is settled outside the ring now!

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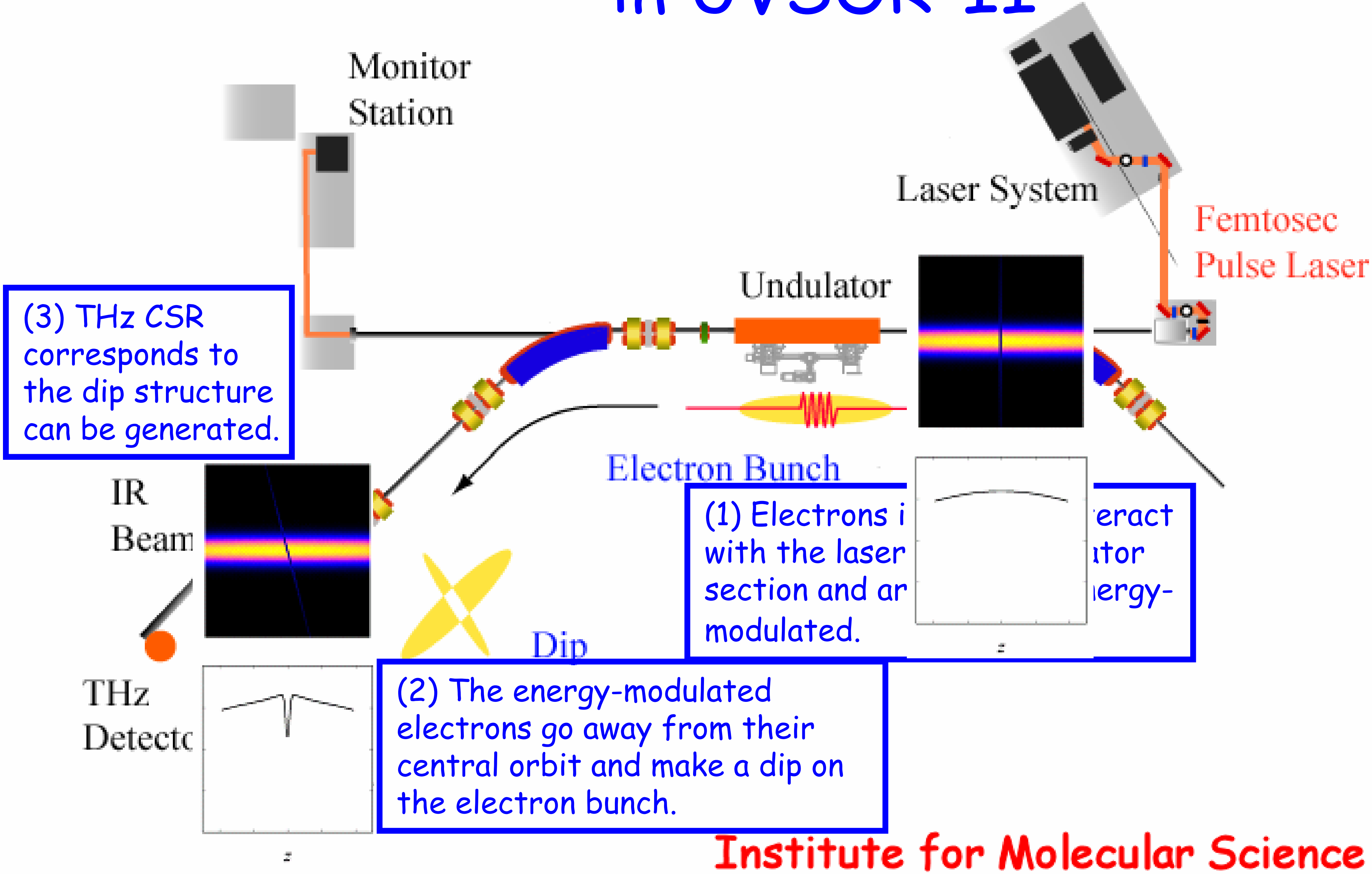
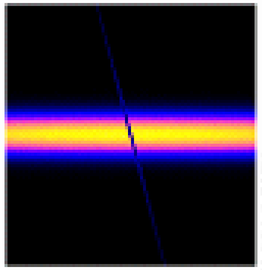
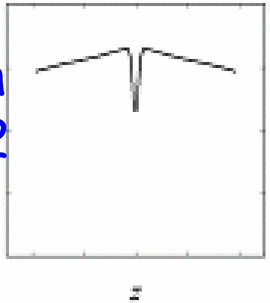
Setup for Laser-bunch slicing in UVSOR-II

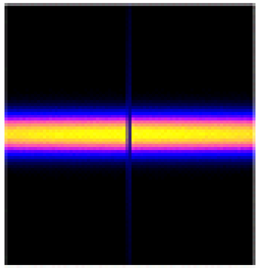


Generation of a Dip on a Bunch

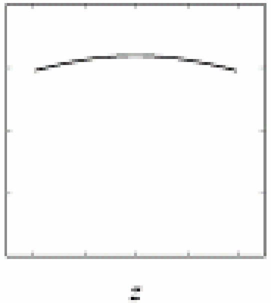
Short laser pulse duration



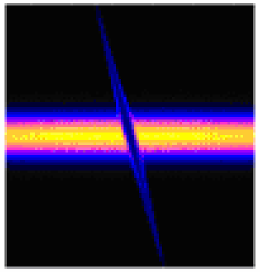


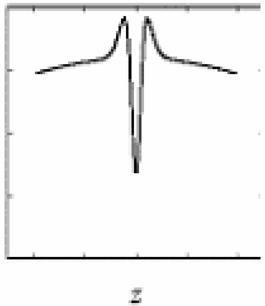


Passing through a section with 2 bending magnets…

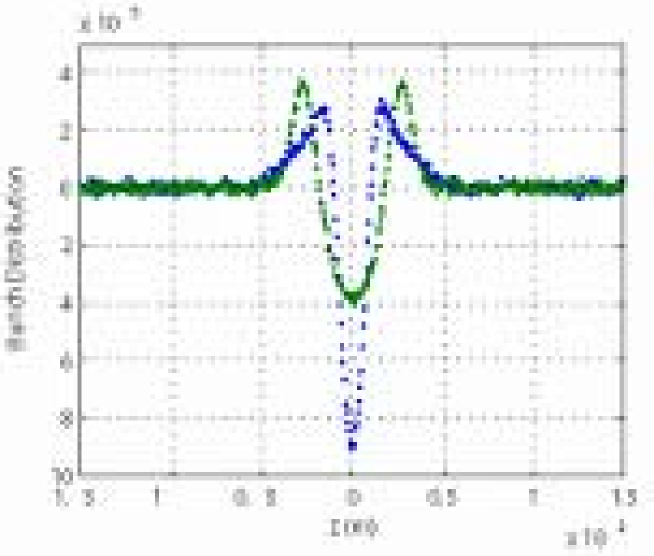


$$z_0 \rightarrow z_1 + \frac{\Delta E_{laser}(z_0)}{E} R_{56}$$



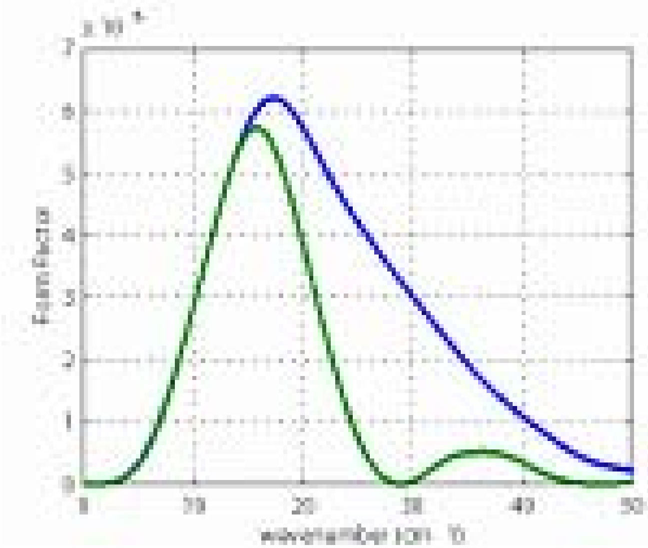


Long laser pulse duration



Examples of dips by short/long laser pulses

Form Factor $F(k) = \left| \int \rho(z) e^{ikz} dz \right|^2$



Form factor from shorter pulse has higher frequency components.

CSR spectrum can change

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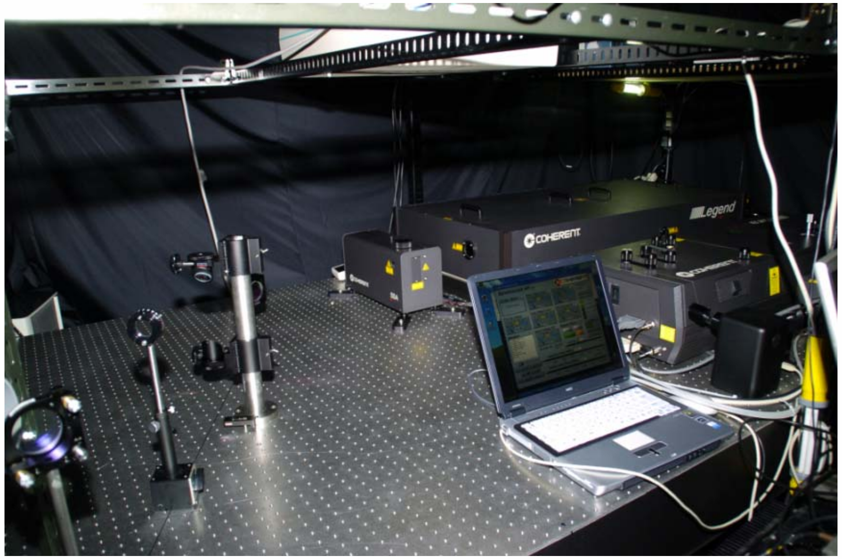
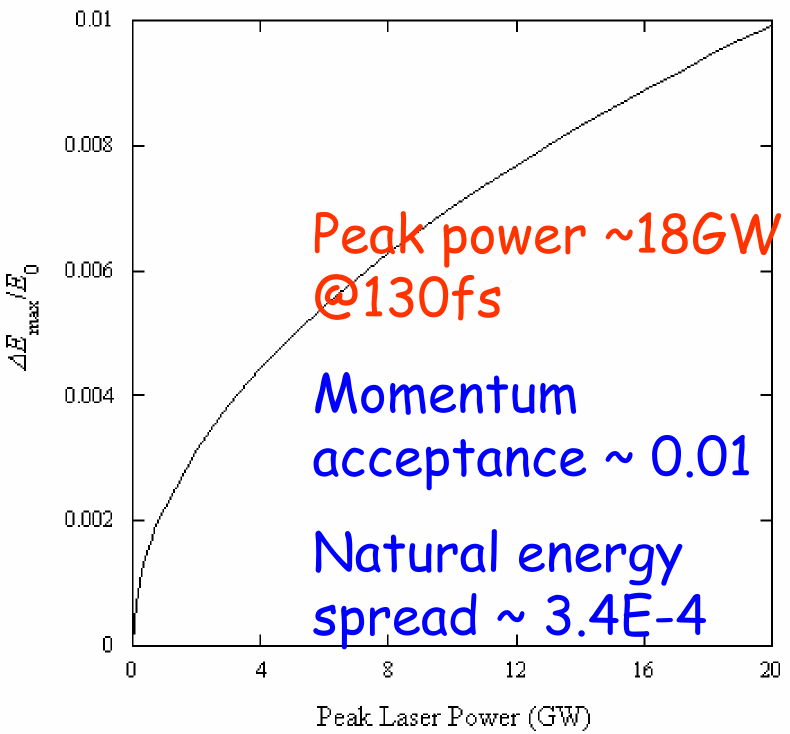
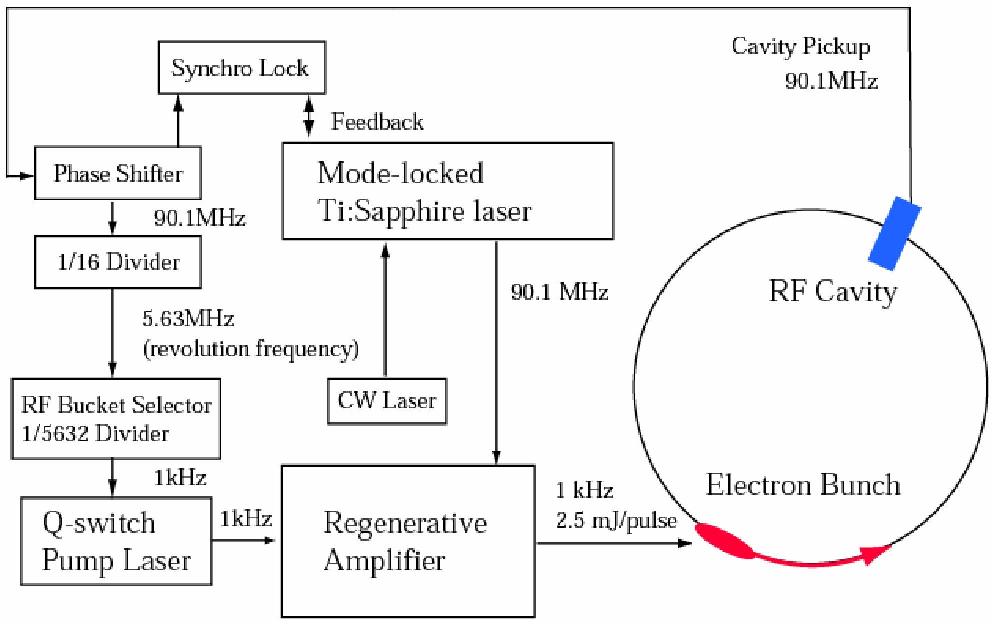
UVSOR II Ti:Sa Laser and Timing System

Pulse Energy 2.5mJ/pulse
Pulse Width 130fs ~ 2ps
Repetiton Rate 1 kHz
(synchronized with RF signal of 90.1MHz)
Wavelength 790 ~ 810nm







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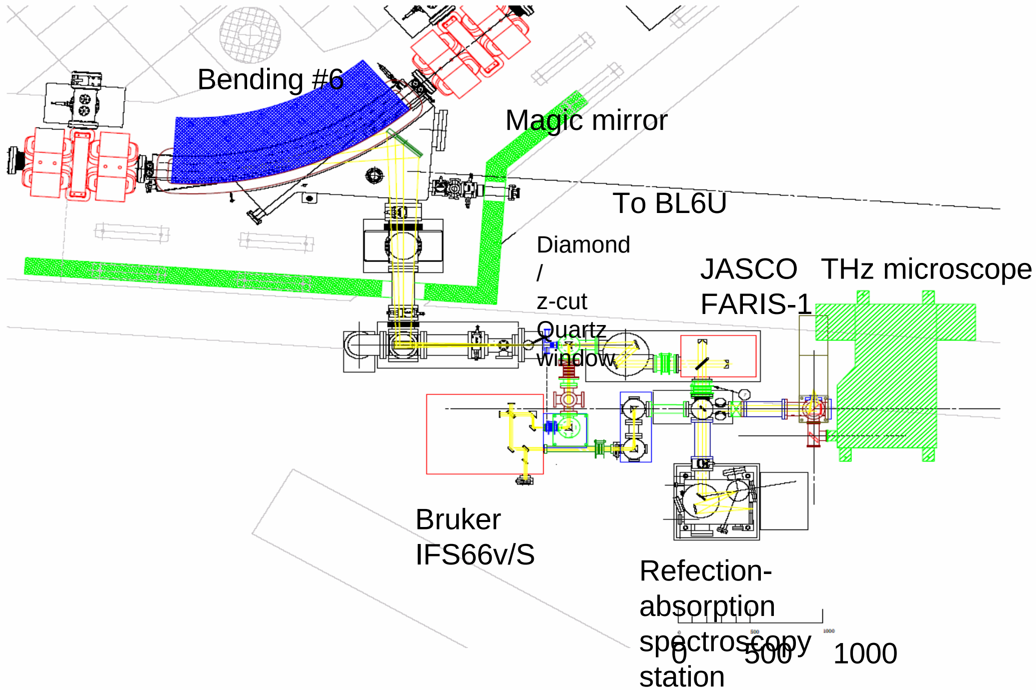
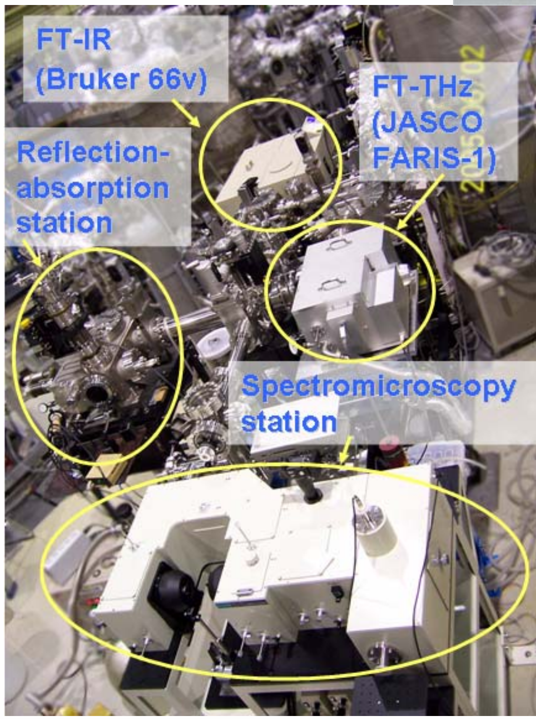
Detection System at BL6B, UVSOR-II

Detector Type	Hot electron (InSb)
Time Resolution	1.6μsec
Spectral Range	3 ~ $50 cm^{-1}$
Sensitivity	5×10^5 V/W (including beam-line optics)
Temperture	4K (cooled by Liq. He)

QMC Instruments Ltd





Martine-Puplett interferometer

Resolution<$0.5 cm^{-1}$

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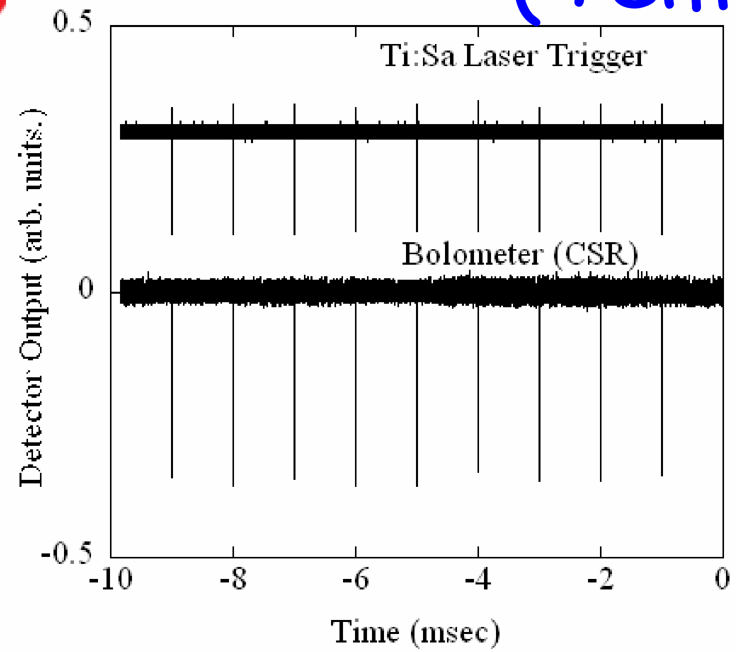
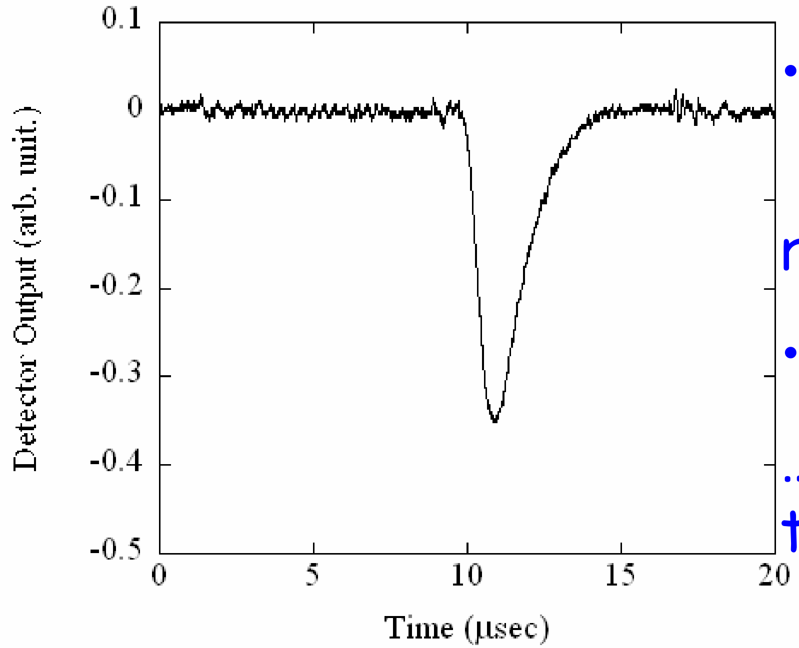
Experimantal Results (Temporal structure)



Temporal relation between the laser trigger and THz signal observed at BL6B.

The intensity of the THz pulse is 10^4 - 10^5 larger than that of the normal THz radiation.



•Pulse width of the single pulse ~ 1.6μs

… that almost corresponds to the response time of the detector.

•Revolution period of the beam = 0.18μs

… detectors that have faster response time are needed !

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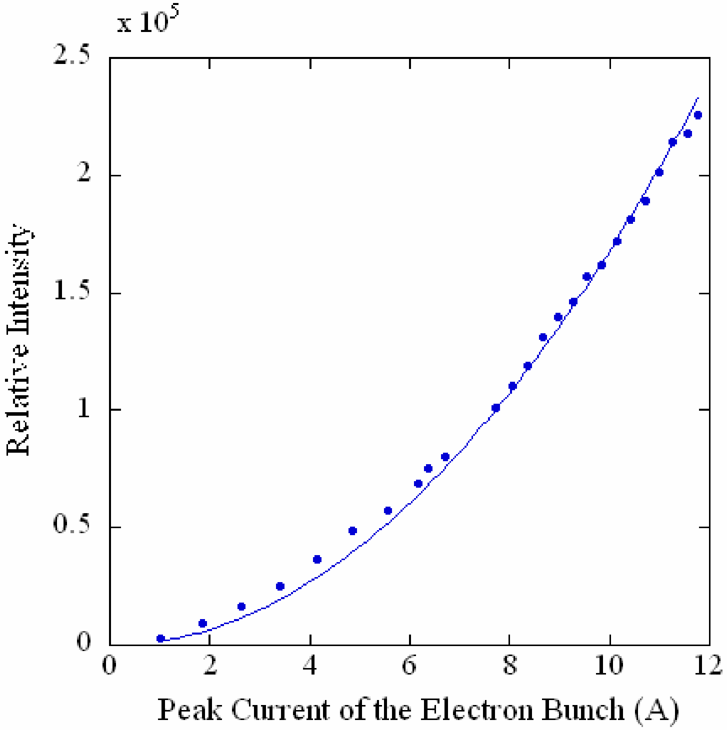
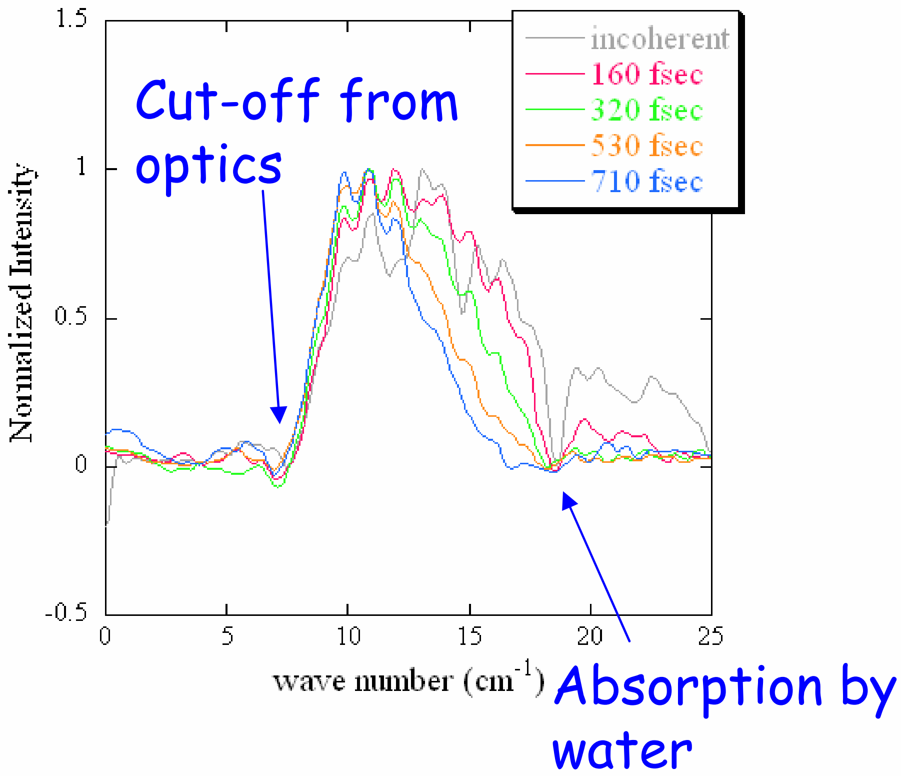
Experimental Results (I_b dependence, Spectrum)





- Squared-dependence of the intensity on the peak current … CSR
- The CSR spectra depend on the pulse duration of the laser … longer laser pulse duration makes longer dip, so that longer wavelength components become coherent radiation.

CSR generation with AM laser pulse

Power spectrum of CSR: $P(k) = N[1+(N-1)F(k)]p(k)$

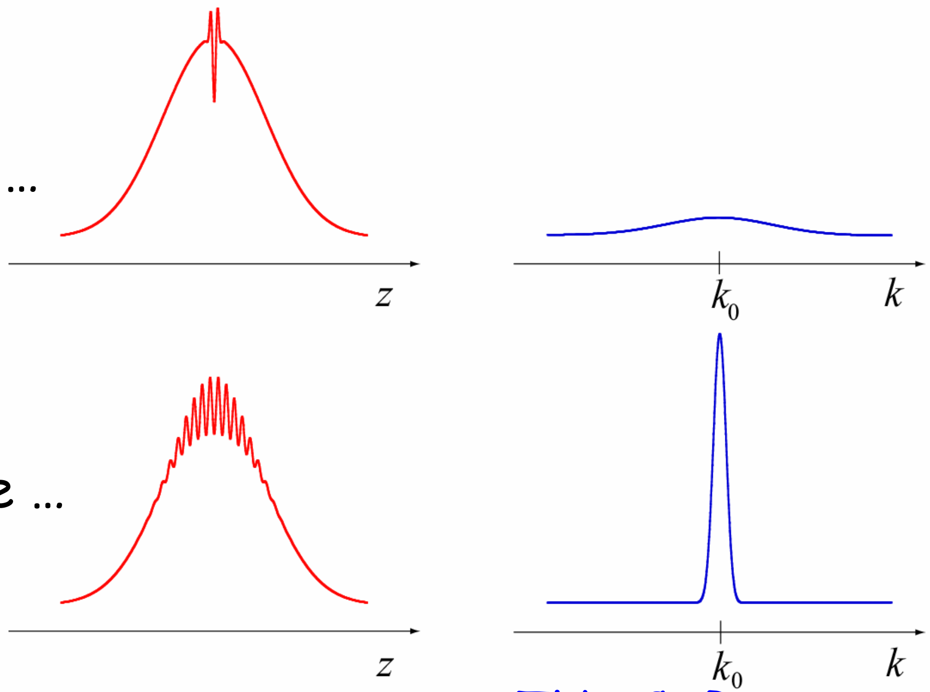
$$F(k) = \left| \int \rho(z) e^{ikz} dz \right|^2$$

$\rho(z)$: Longitudinal electronic distribution

Single pulse …

Modulated pulse …

(with M-peaks)



- Wide spectrum
- Small spectral peak
- Narrow spectrum $\propto 1/M$
- Large spectral peak $\propto M^2$

Electronic distribution

THz CSR spectrum

(excluding whole bunch component)

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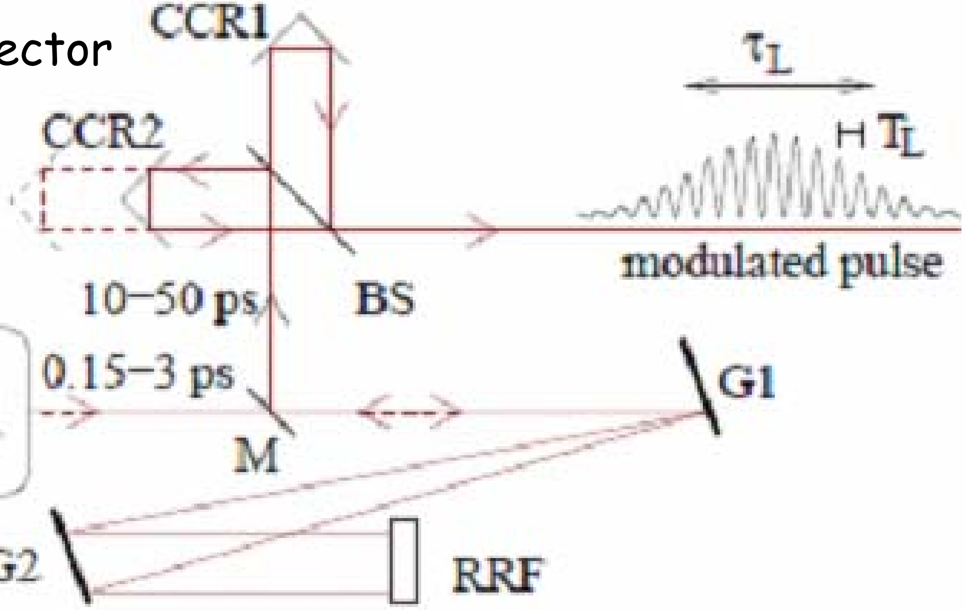
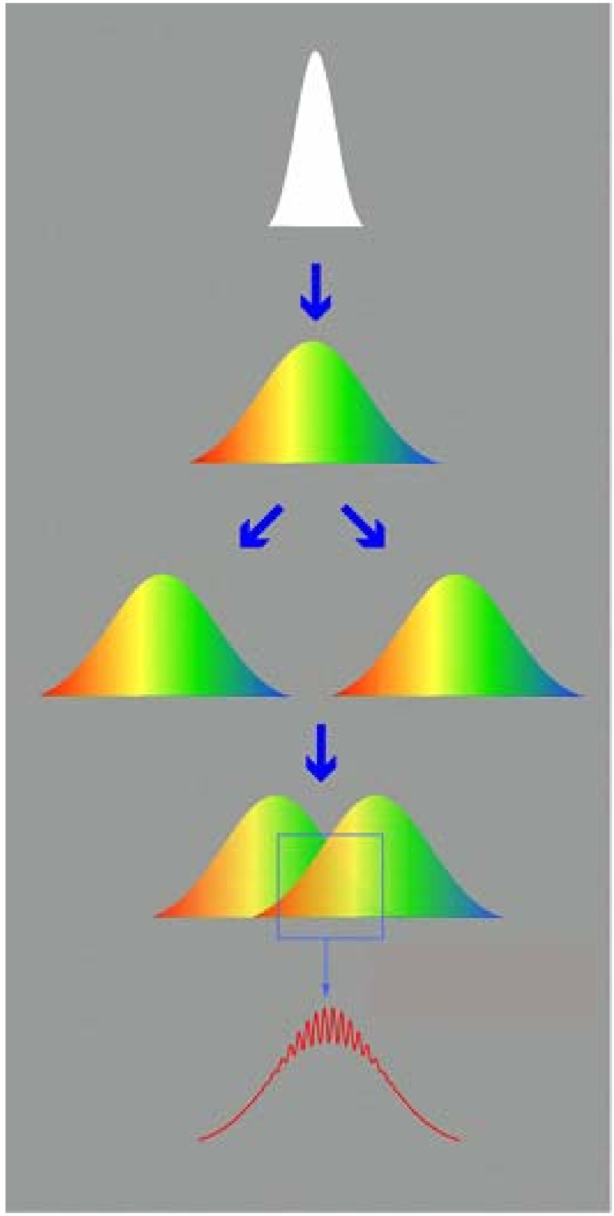
'Chirped pulse beating'

Weling, A.S & Auston, D.H, J. Opt. Soc. Am. B 13, 2783-2791 (1996)

- CCR, RRF : retroreflector
- BS : beam splitter
- G1, G2 : gratings





1. Making chirp on the laser pulse with a pair of gratings

$$E(t) \propto \exp(-i\omega t - at^2)$$

2. Leading the chirped pulses to the Michelson interfelometer, and adjusting optical delay.

Generation of the beat structure that corresponds to the frequency difference between two chirped pulses

$$I = |E(t+\tau/2) + E(t-\tau/2)|^2$$
$$= C_1 + C_2 \cos[2\,\mathrm{Im}(a)t\tau + \omega\tau]$$

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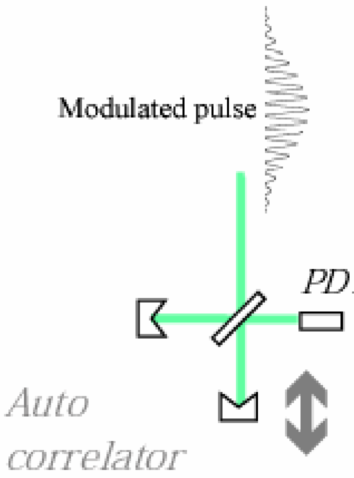
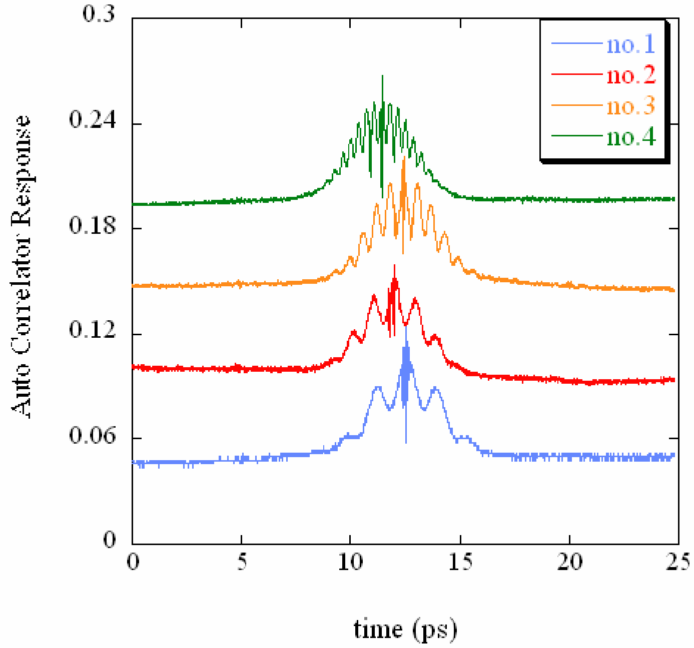
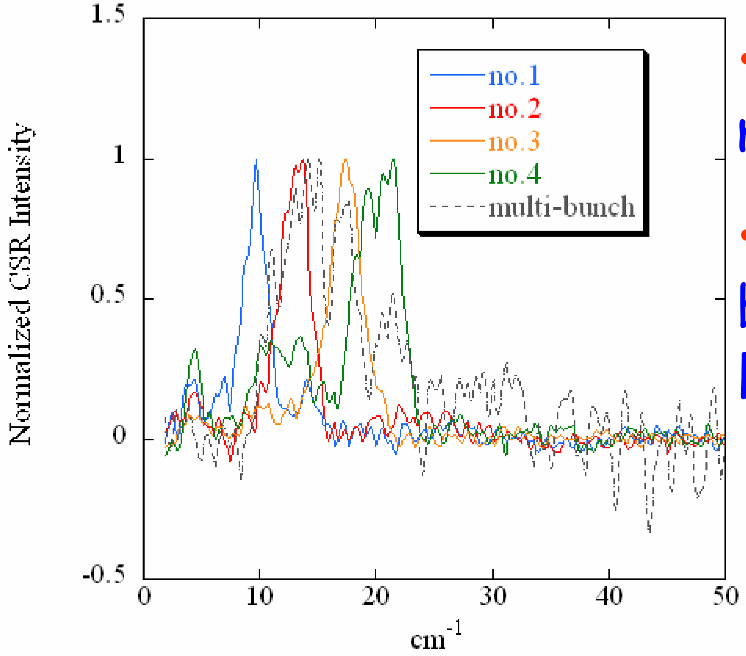
Modulated laser pulse and related CSR spectrum



Measurement of the modulated laser pulse with auto correlator





- Narrower spectral width with the modulated laser pulse
- The spectral peak frequency is tunable by changing the beat structure of the laser.

Band width ~ 4cm-1

@ pulse duration = 1 ~ 2 ps

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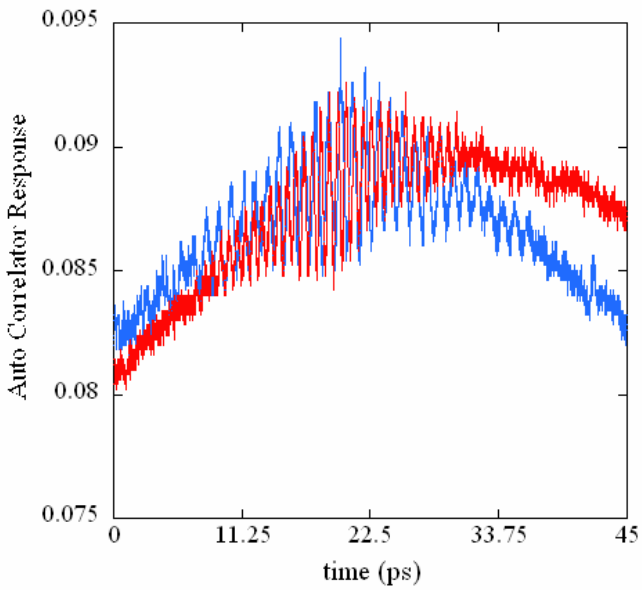
Output from auto-correlator

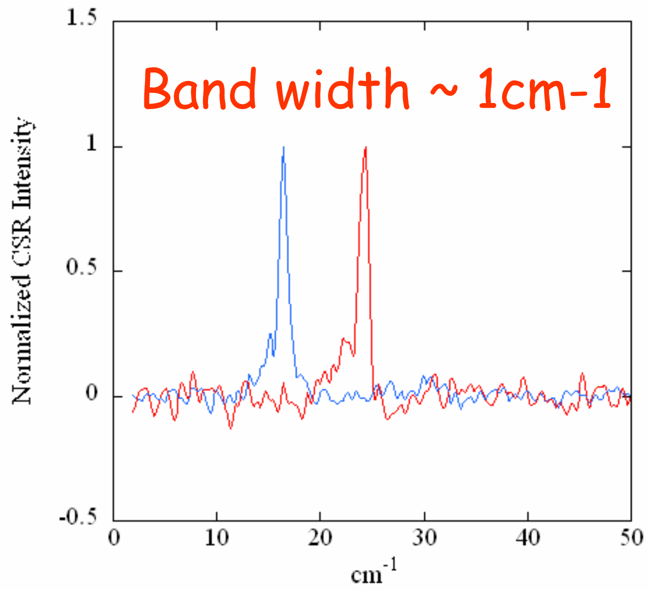
CSR spectrum

Laser pulse duration

60ps

(much beating)

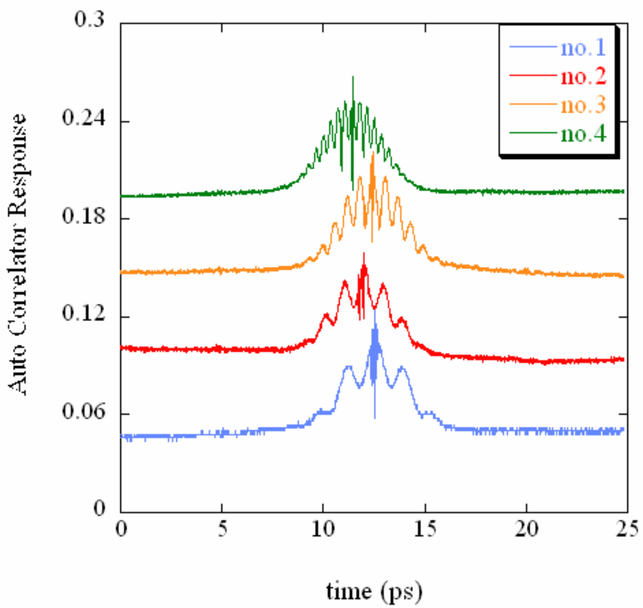




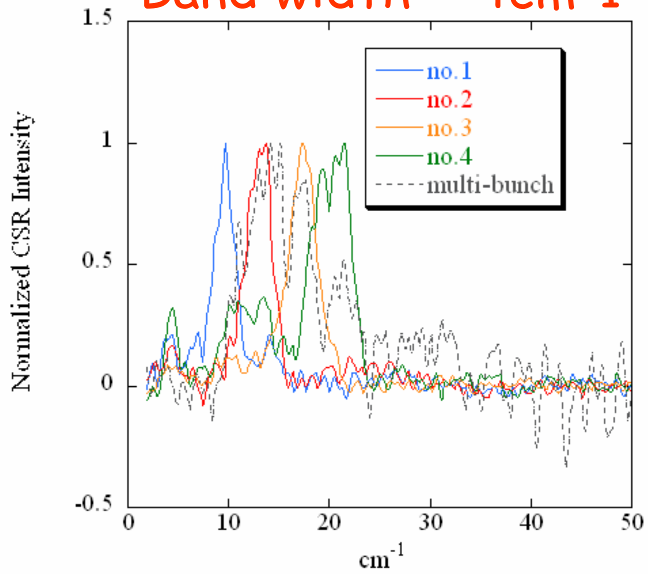
Laser pulse duration

1~2 ps

(less beating)



Band width ~ 4cm-1



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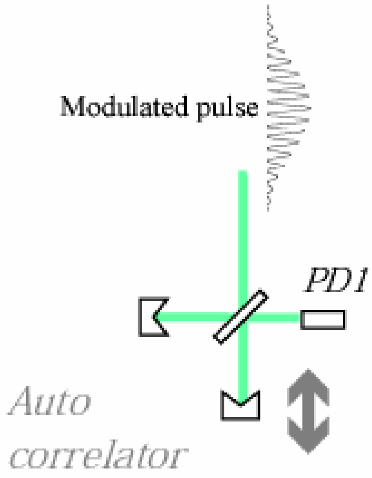
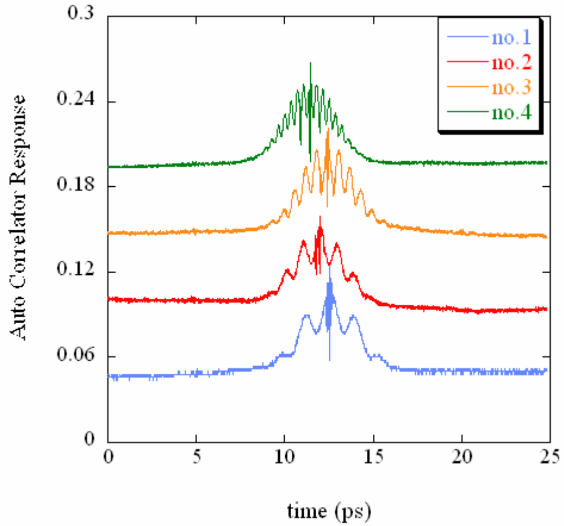
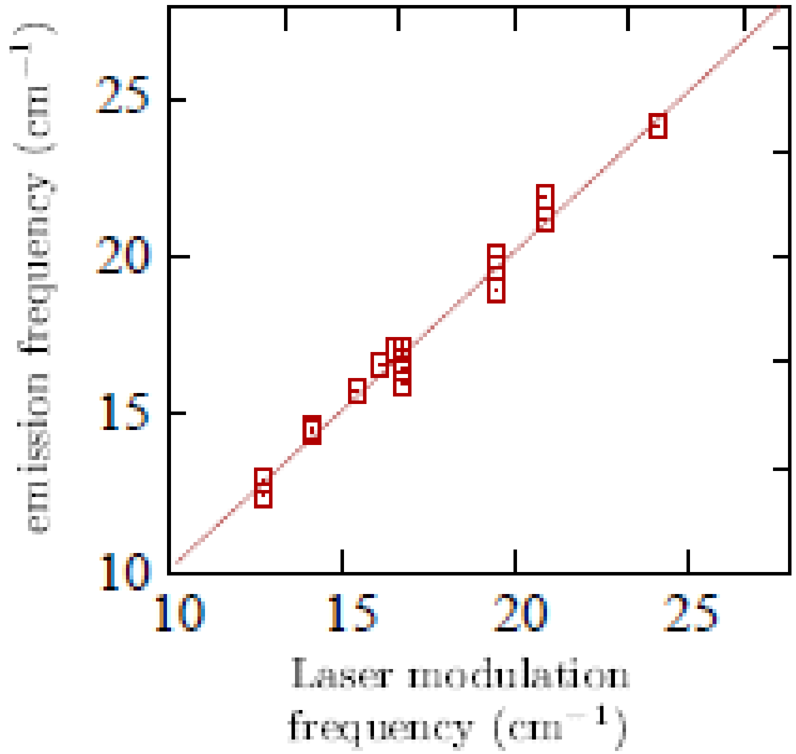
Changing CSR frequency





We changed the beating frequency and estimated the laser modulation frequency from the auto-correlator measurement



Clear correlation between the laser frequency and the CSR peak spectrum

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Summary

- We have observed intense THz synchrotron radiation by laser-bunch slicing method in UVSOR-II.
  - squared dependence of the peak intensity on the peak current … CSR
  - band width depends on the pulse duration of the laser
- THz CSR generation with AM laser pulse
  - narrow band THz CSR
  - peak frequency depends on the AM (tunable)