Intense coherent THz synchrotron radiation induced by a storage ring FEL seeded with a femtosecond laser

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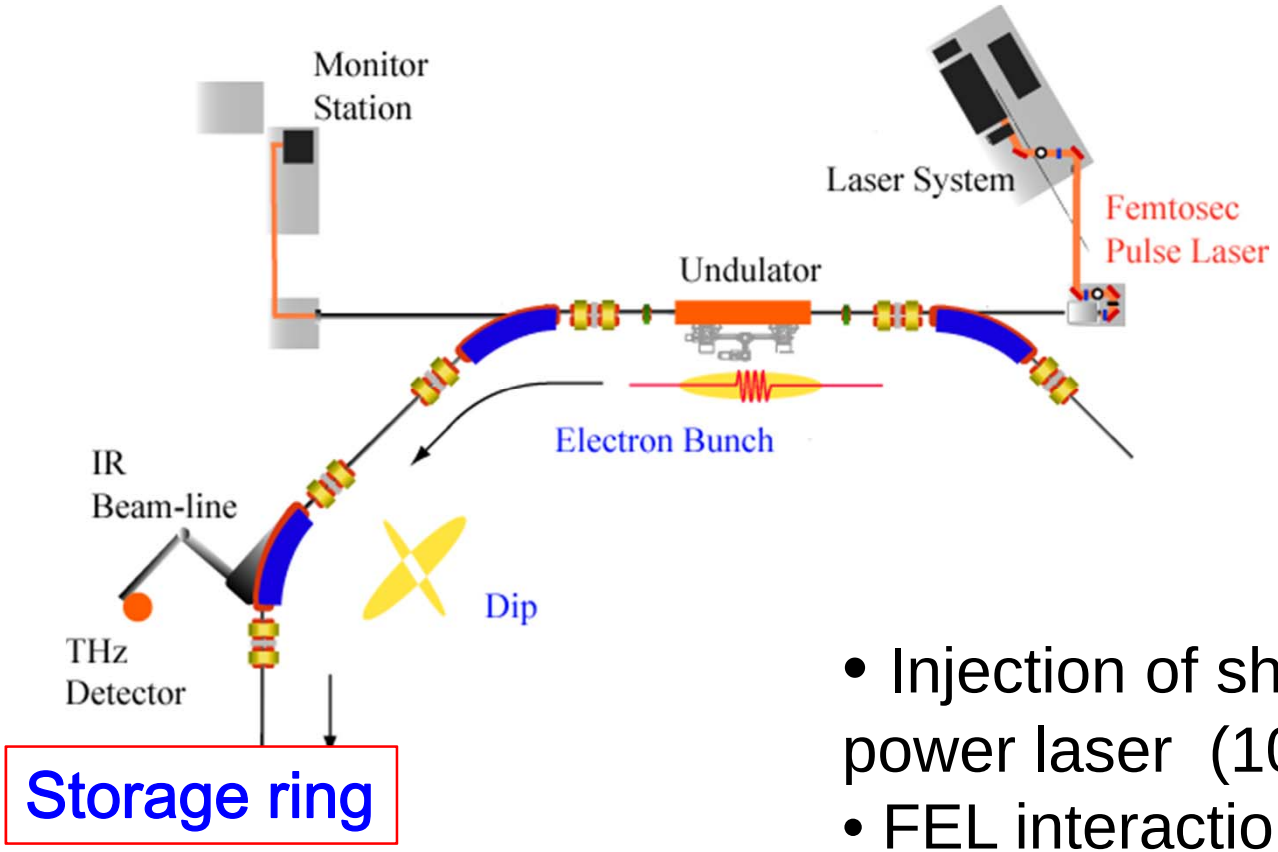
Contents

- Laser bunch slicing and coherent synchrotron radiation (CSR)

  Example: UVSOR experiment:

- Storage ring FEL
- Seeded storage ring FEL experiment
- Summary

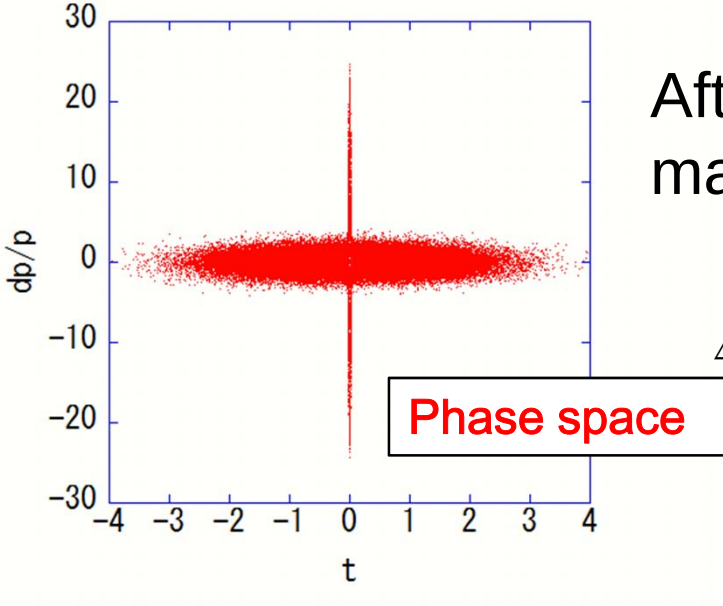
Laser Bunch Slicing and Coherent Synchrotron Radiation (CSR)



BESSY, ALS, UVSOR-II etc.

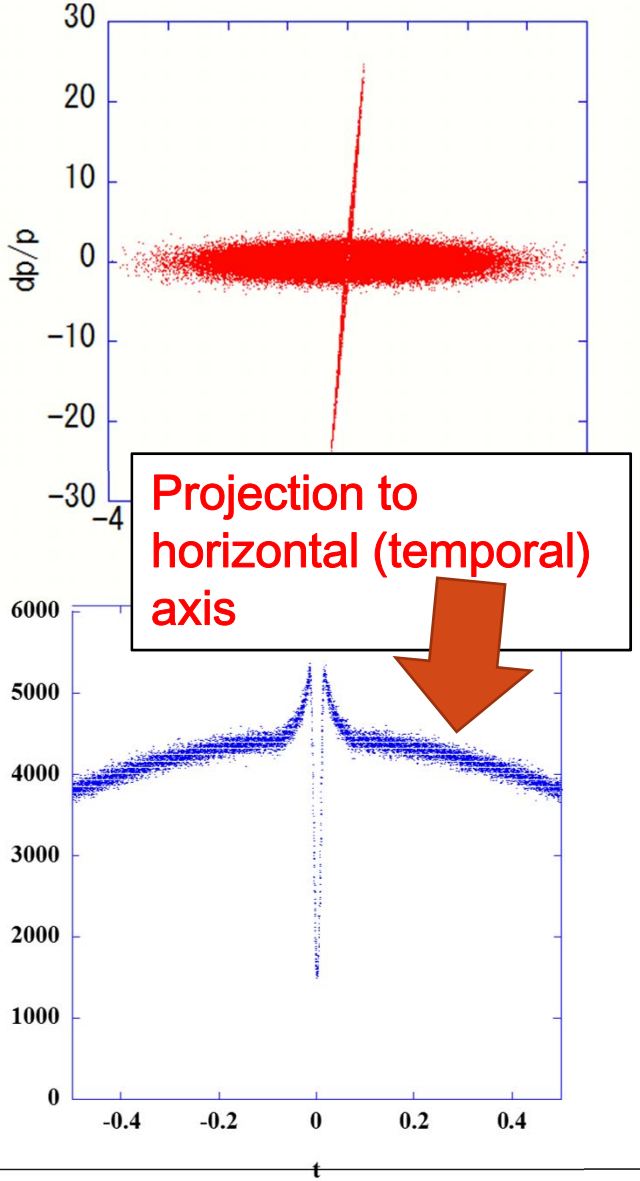
- Injection of short pulse high power laser (100 fsec, 10 GW).
- FEL interaction between the laser and electron beam inside undulator.

Laser Bunch Slicing and CSR (Cont.)



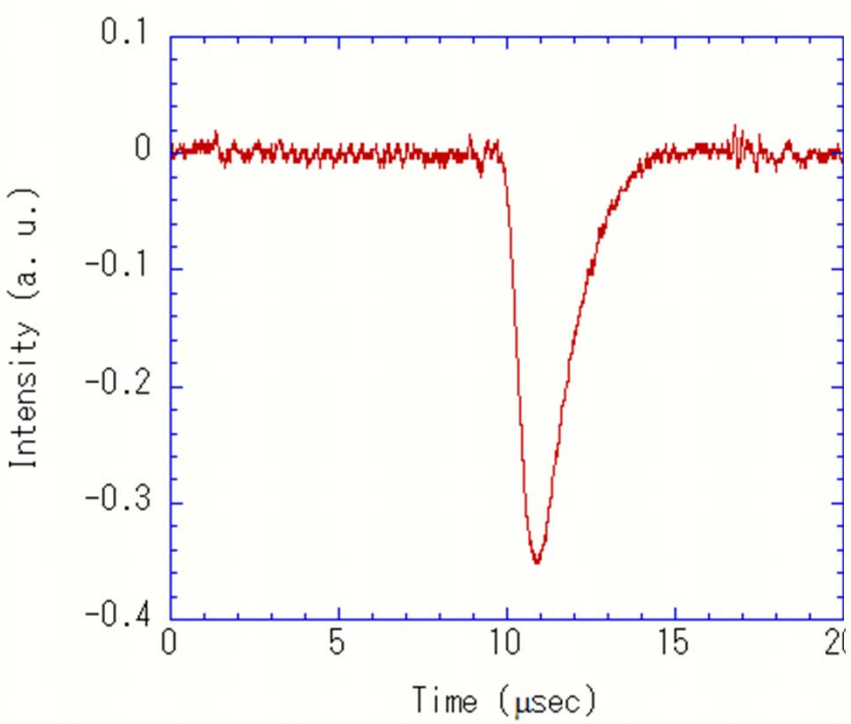
After bending magnet(s)

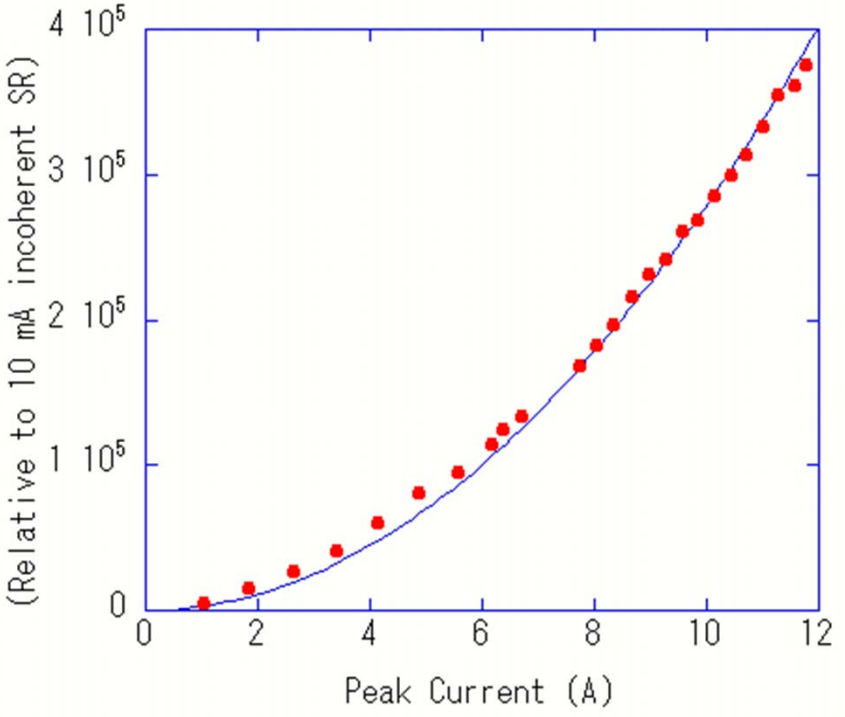
$\triangle z = R_{56} \triangle e/E$



- Local energy modulation is created.
- After bending magnet, it is converted to density modulation (time of flight dispersion).
- CSR is generated due to the micro-structure.

Laser Bunch Slicing and CSR (Cont.)





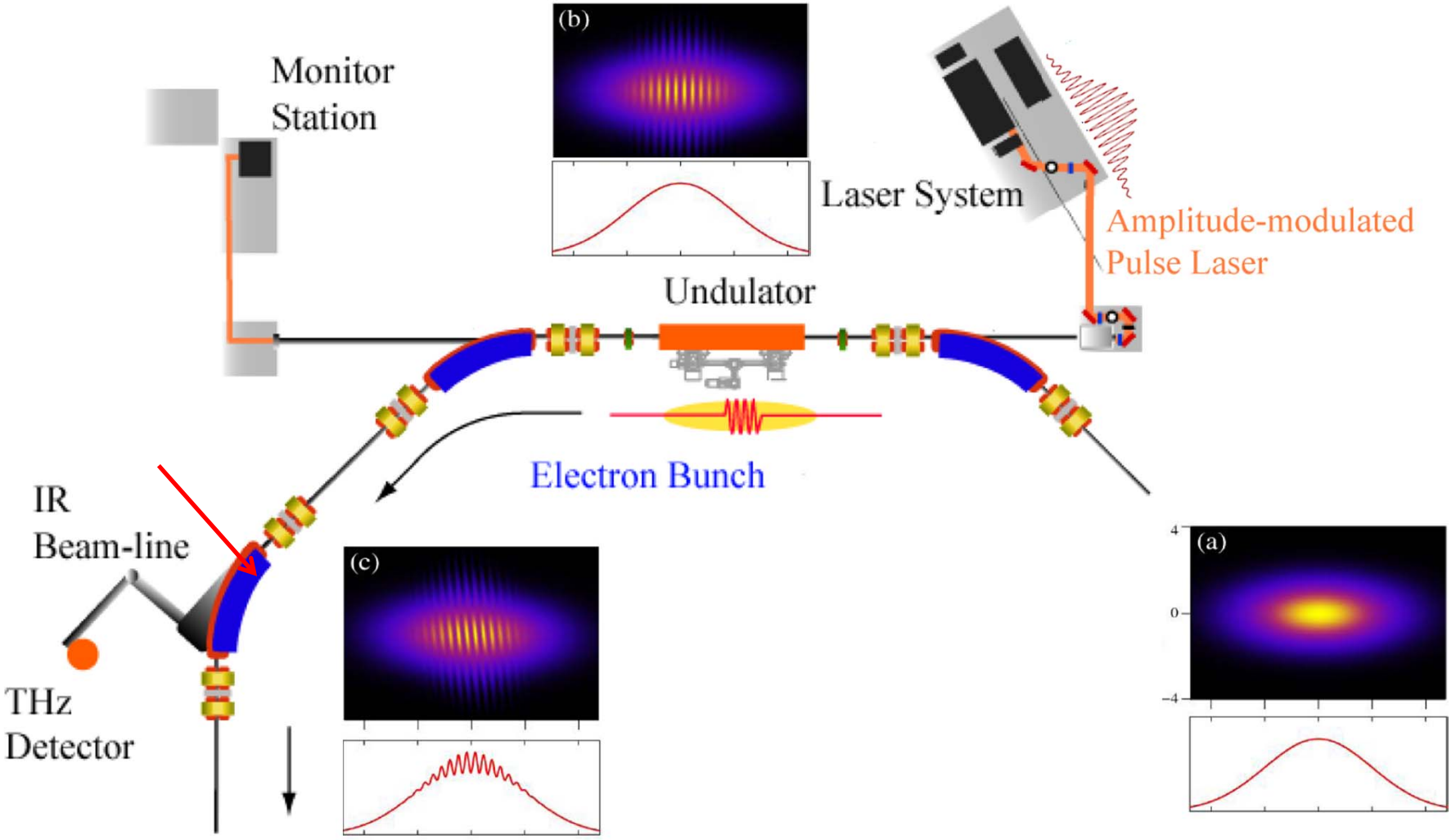
M. Shimada
et al. JJAP 46
(2007) 7939

Power radiated by N electrons

$= N^2$ x Power radiated by 1 electron

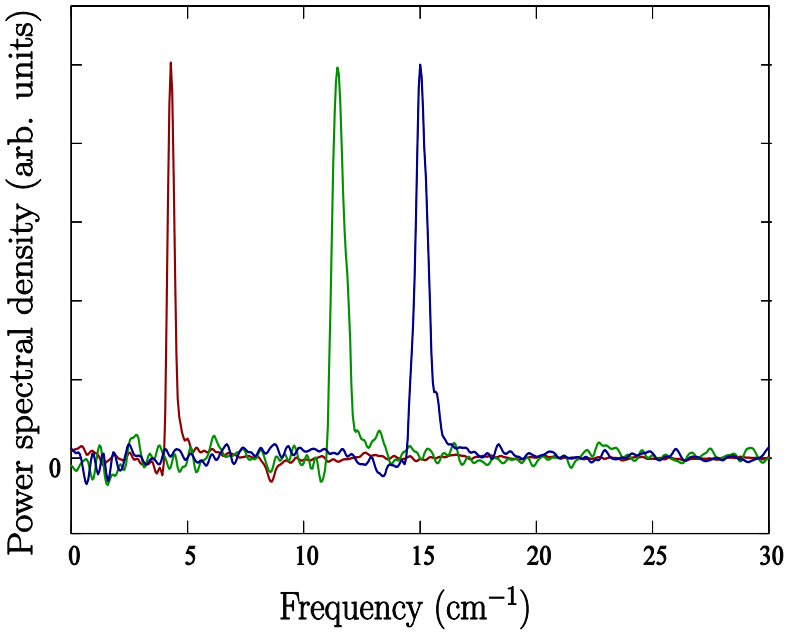
Spectrum ~ Fourier transform of $\rho(z)$

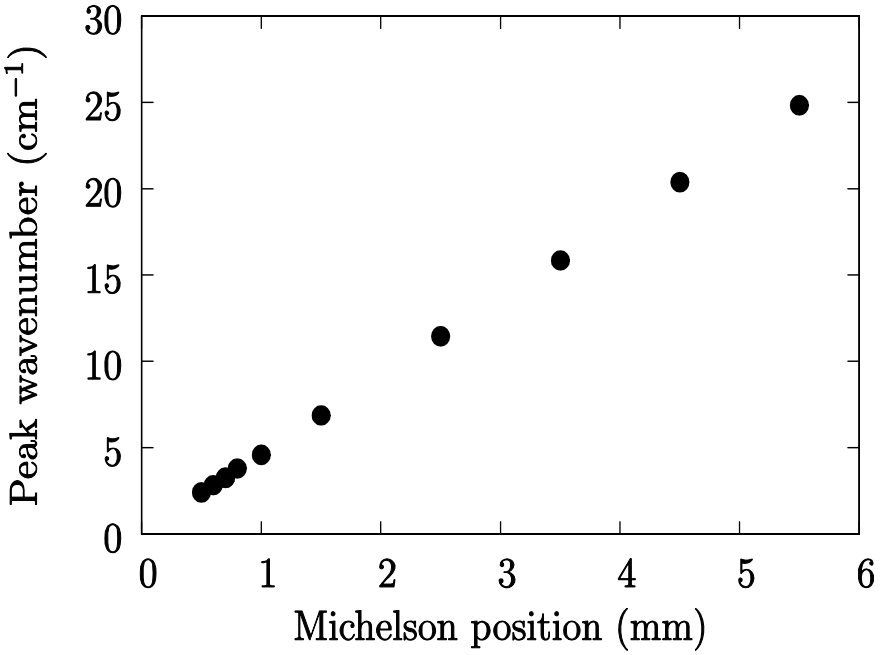
Narrow-band CSR (@UVSOR-II)



S. Bielawski et al. Nature Physics, 4, 390–393 (2008)

Narrow-band Coherent Synchrotron Radiation :Measured spectra

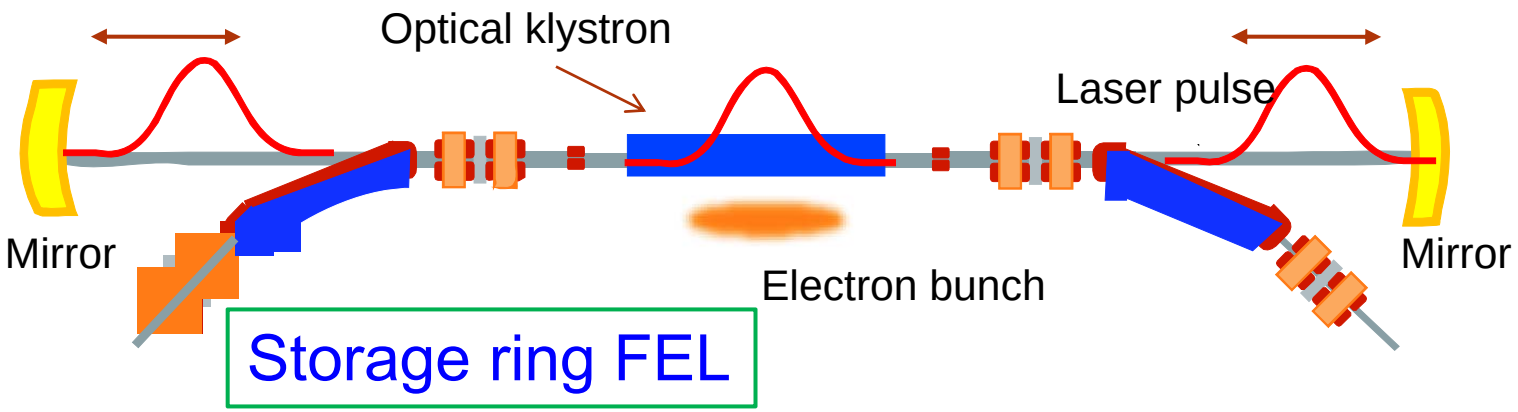




"Tunable" "Narrow Band" CSR"

Application of narrow band CSR:
H. Zen et al. TUPA 14

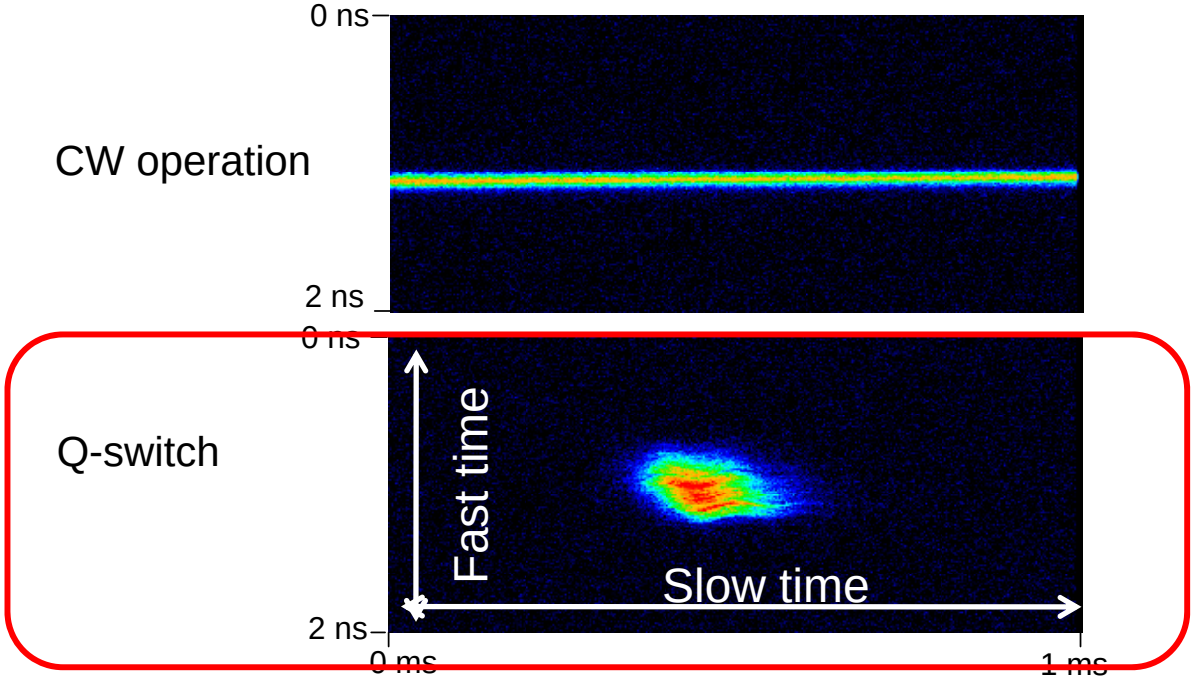
CSR using a storage ring FEL (an internal laser) instead of an external short pulse laser. Why SR-FEL?



- Storage ring FEL repetition rate is ~ 10 MHz !
- Ordinal CSR (or Bunch slice): repetition rate is limited by laser repetition (~ 1 kHz or less)
- Using SR-FEL, CSR with much higher repetition rate is expected.

Why Q-switch SR-FEL ?

- In storage ring, there are two types of lasing, CW lasing and repetitive Q-switch lasing .
- In Q-switch mode, rf modulation technique is used and a higher peak power is available.



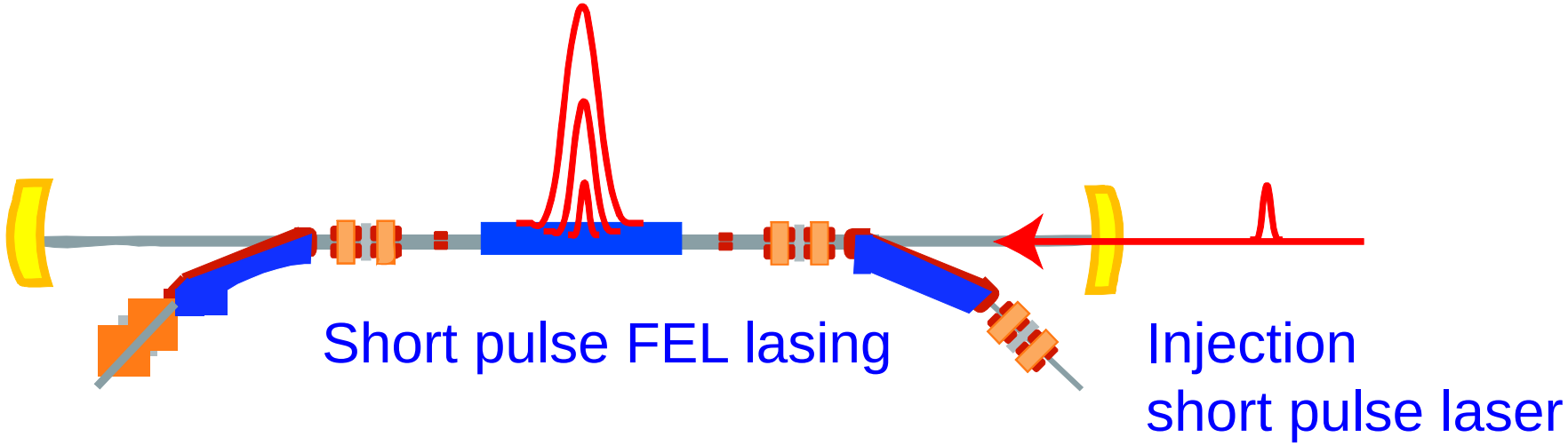
Streak camera image of temporal structure of FEL

- In stable CW lasing, the laser pulse width is determined by an equilibrium condition.

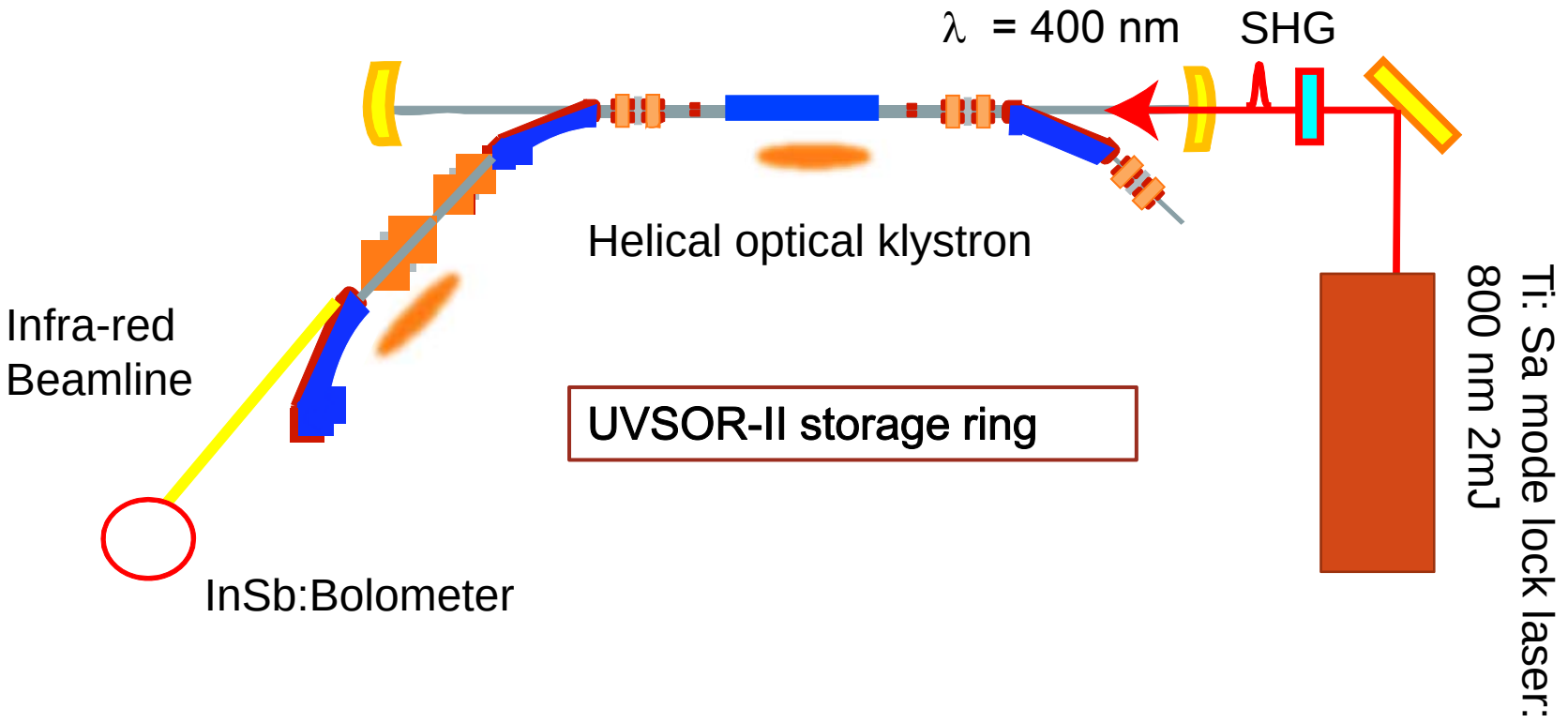
Short pulse lasing is difficult

Why Q-switch SR-FEL ?

- In Q-switch lasing, the lasing starts from noise.
- If short pulse laser is injected to Q-switch FEL as seed, short pulse lasing is expected.
- Long sustain high repetition rate CSR (or bunch slice) is expected.



Experimental setup



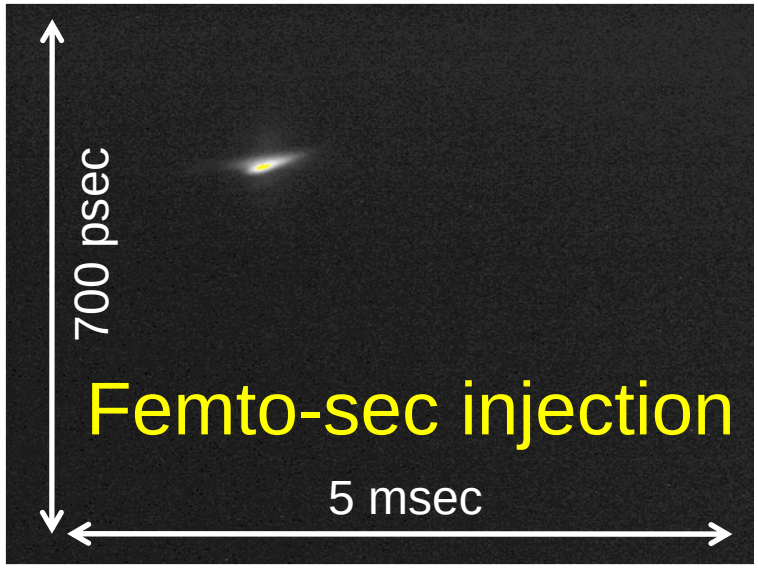
Laser : Second harmonics of Ti:Sa laser

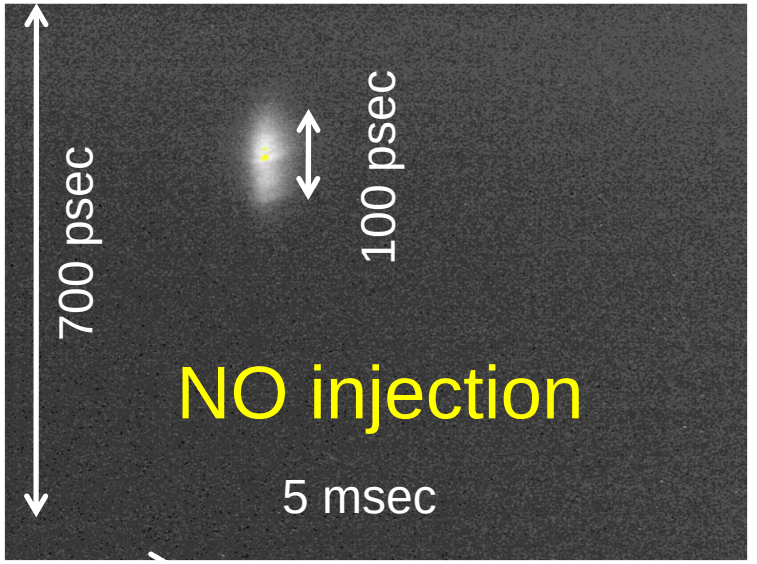
: Pulse width: 300 fsec –FWHM or ~ 100 psec-FWHM

Undulator: Helical optical klystron 400 nm

C. Szwaj TUPB05
H. Zen WEPA17

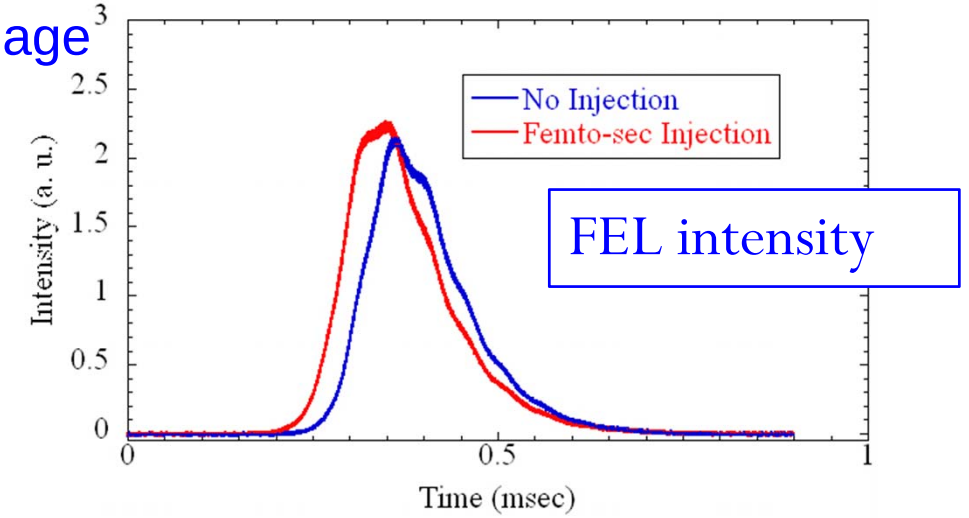
Experimental result (streak camera)





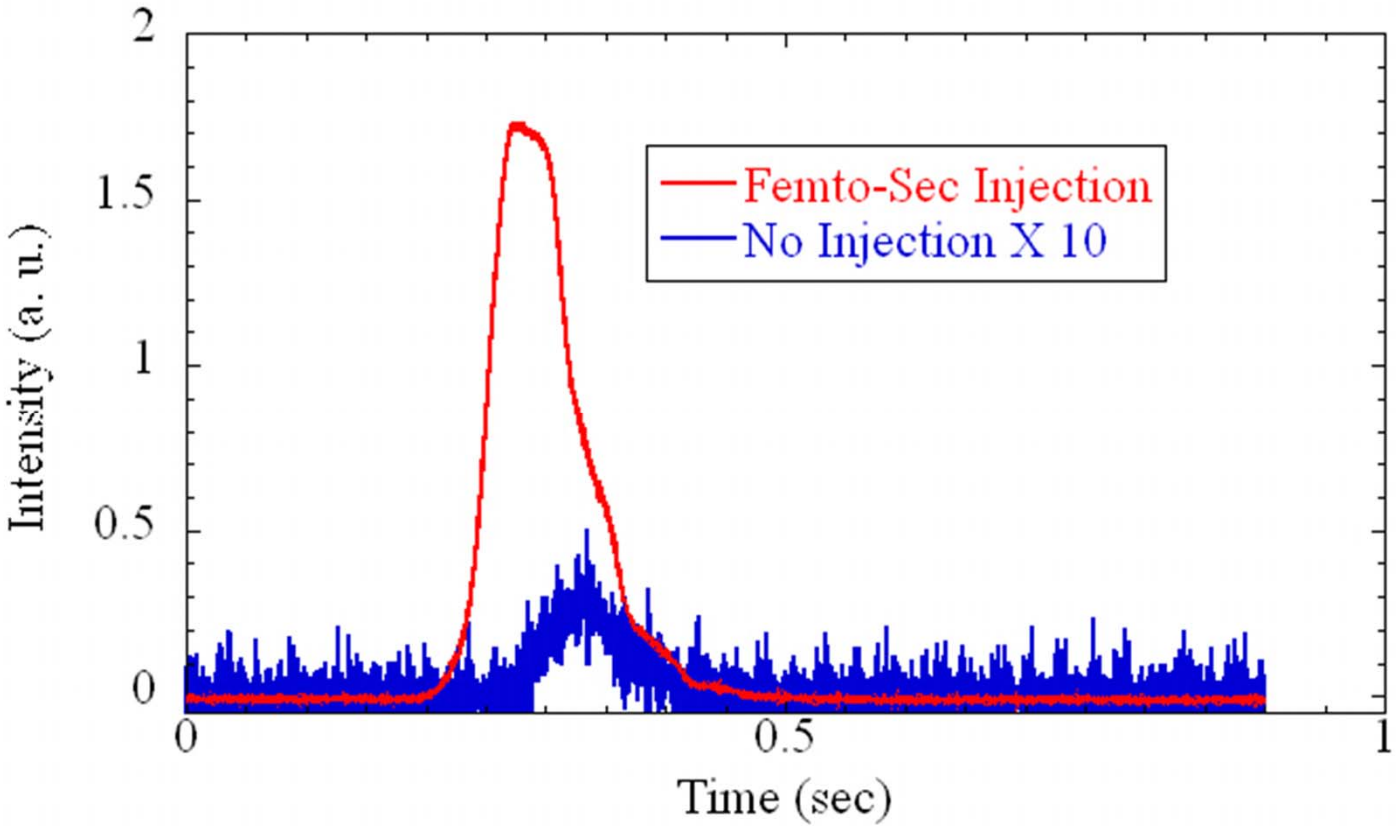
Streak Camera Image

- Short pulse lasing
(Shorter than s.c. resolution)
- Faster rise time
- Intensity is not so changed.



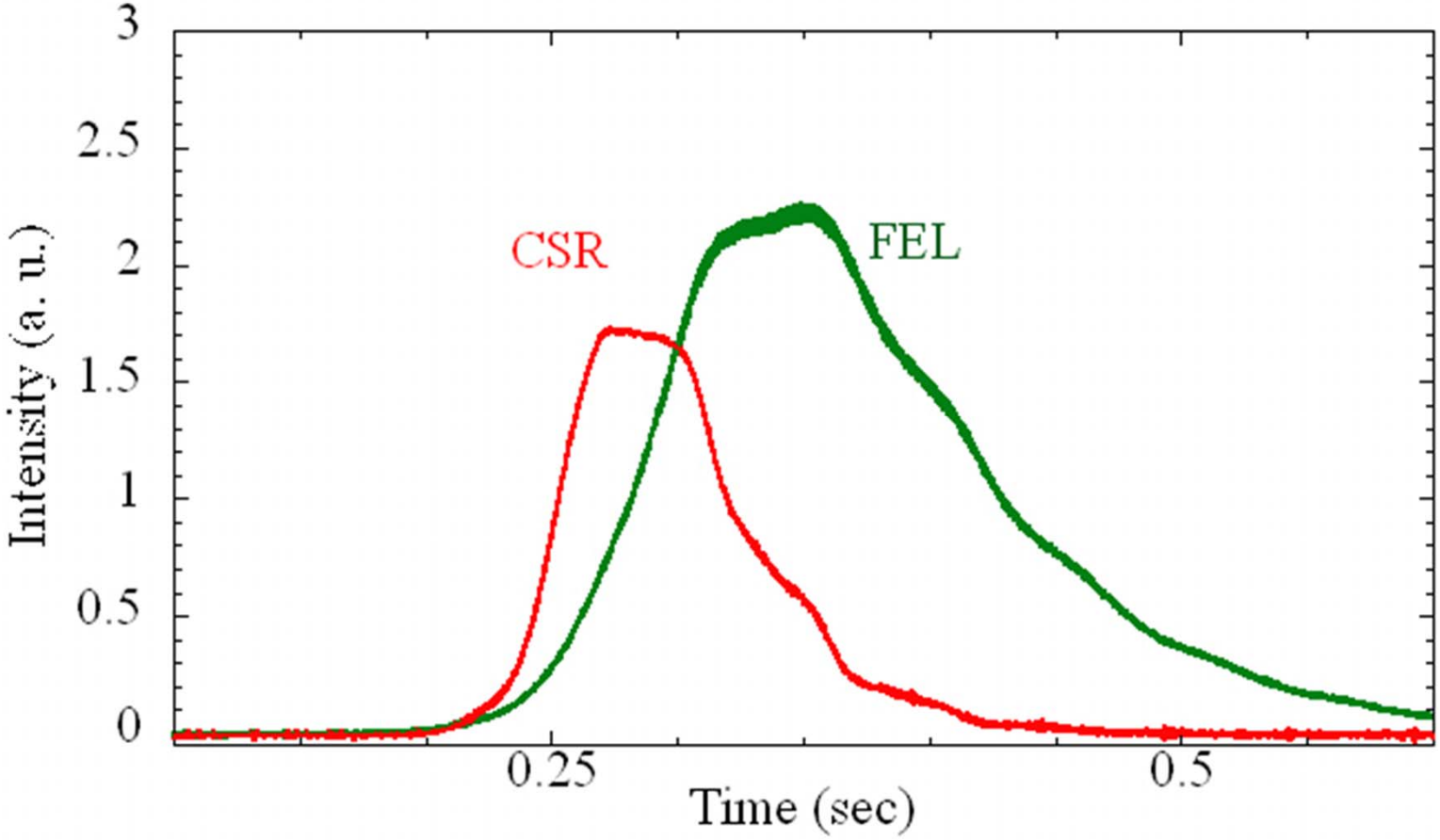
FEL intensity

Experimental result (CSR)



CSR intensity increases 50 times
(as compared the case no injection)

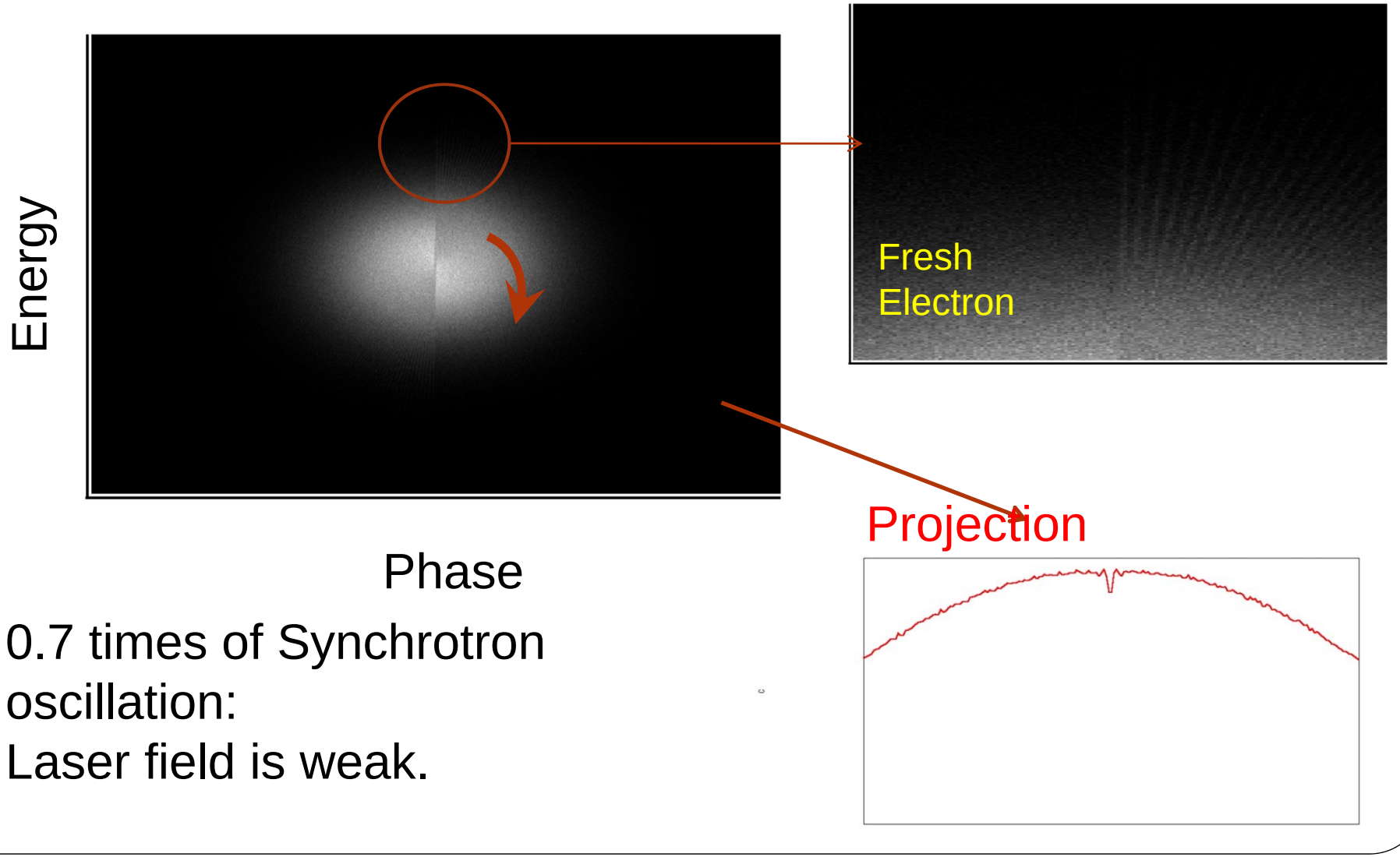
Experimental result (FEL& CSR)



Simultaneous measurement of CSR and FEL

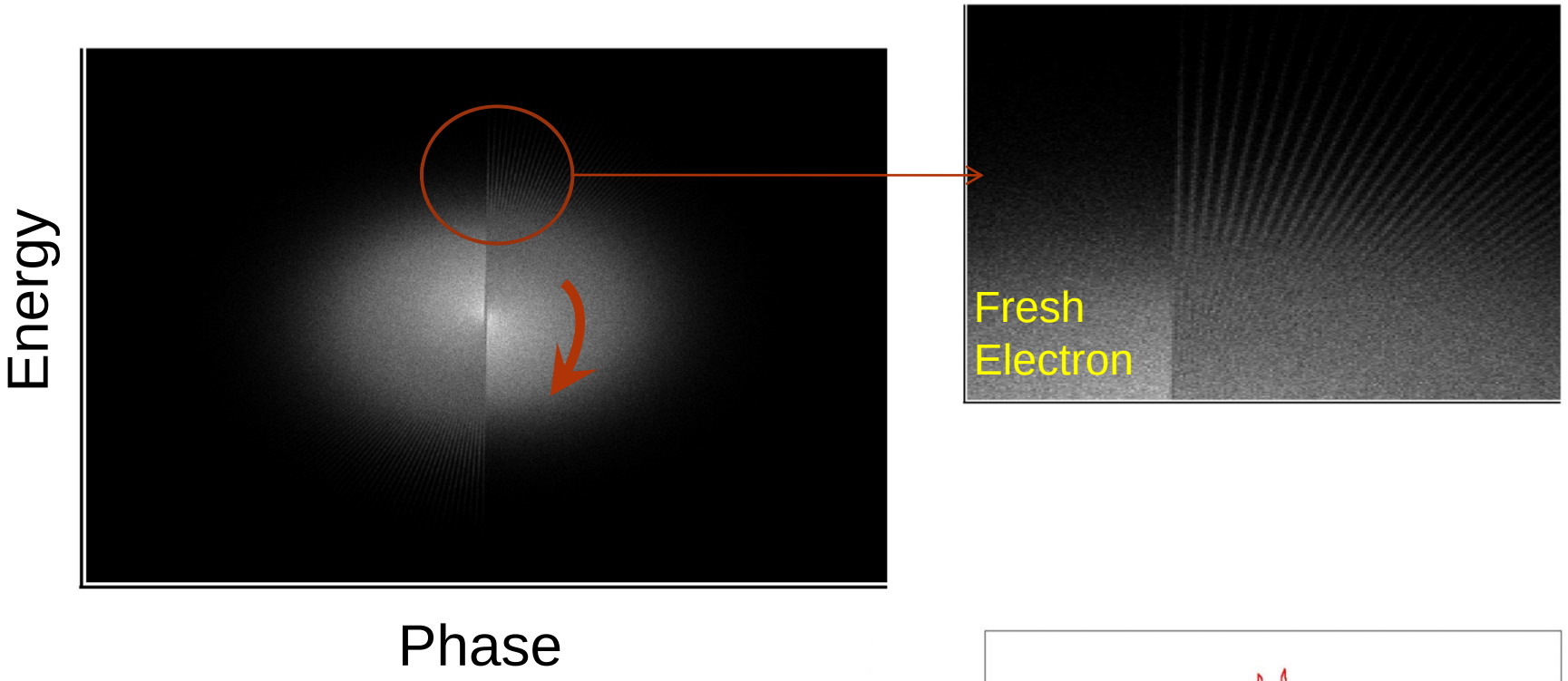
- CSR is produced in early stage of the lasing

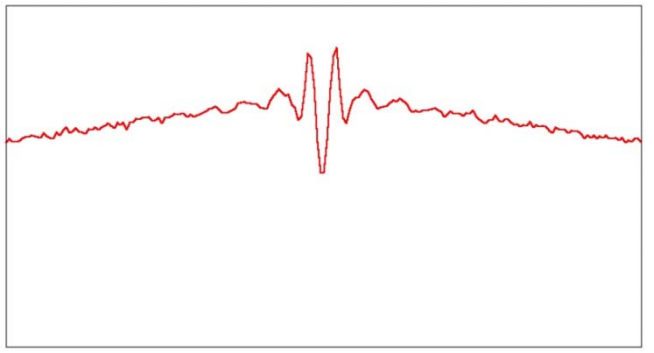
Simple phase space simulation(1)



0.7 times of Synchrotron oscillation:
Laser field is weak.

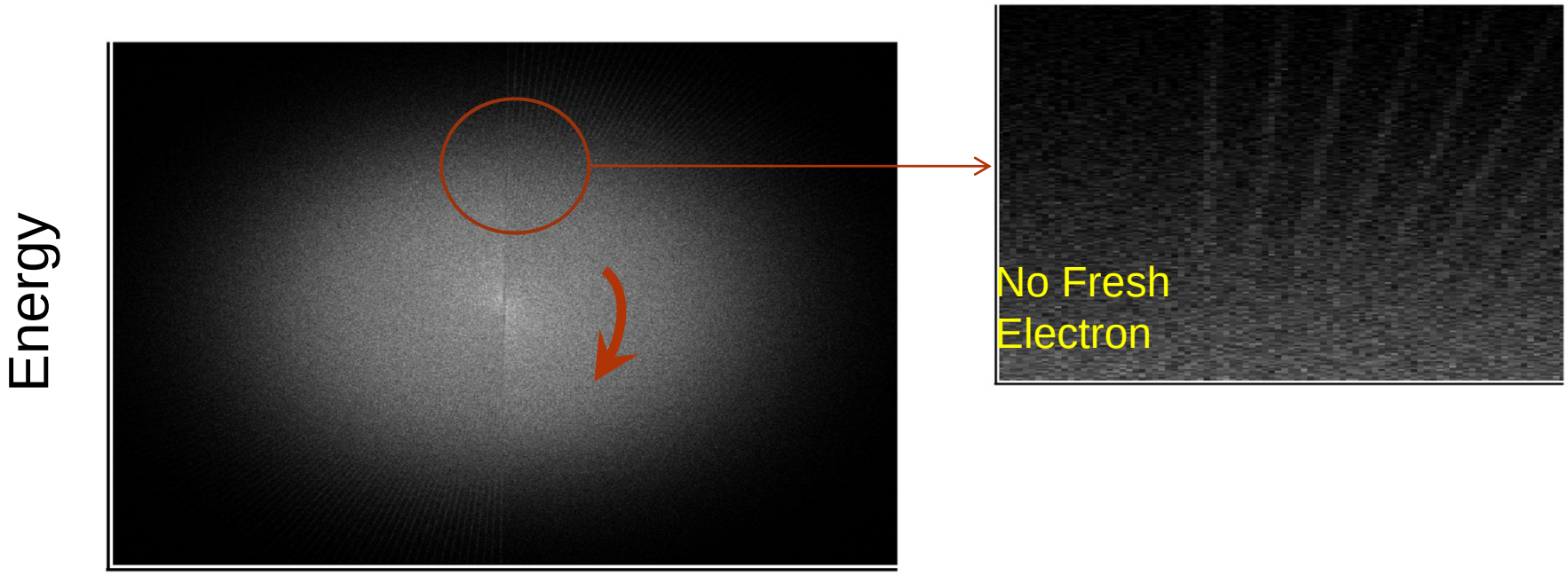
Simple phase space simulation (2)





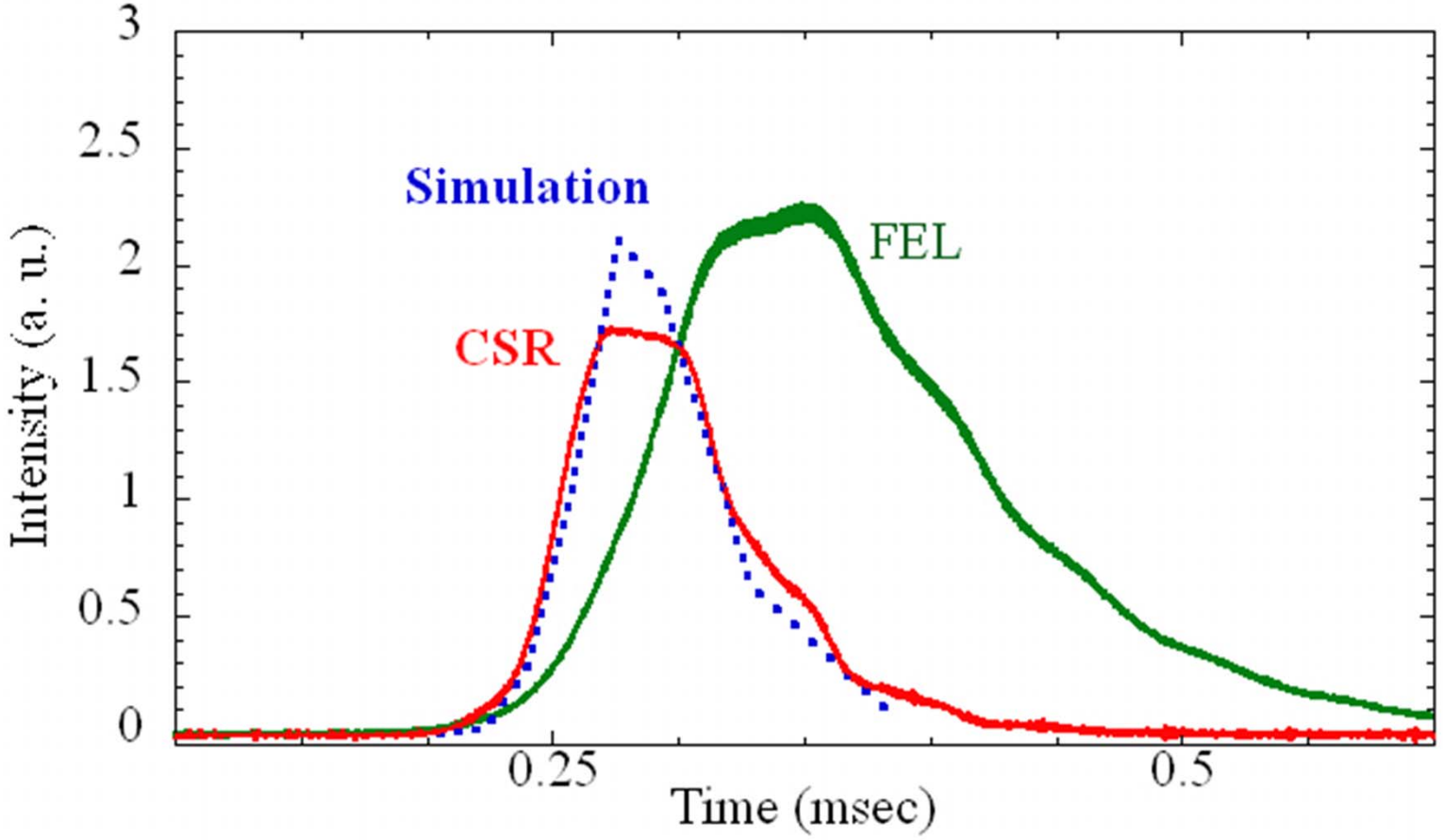
1.5 times of Synchrotron oscillation :
Laser field is strong

Simple phase space simulation (3)



3.5 times of
Synchrotron oscillation
Laser field is strong

Simple phase space simulation (4)



Simulation almost reproduces the experimental result.
Detailed calculation is in progress.

Summary

◆Succeeded in Q-switch FEL lasing seeded by femto-sec laser
◆Intense CSR production is observed
◆Simple simulation is made, detailed simulation is in progress.

Future Applications:
●Bunch slice to produce short pulse SR
●Injection of the amplitude modulated laser to produce narrow band CSR