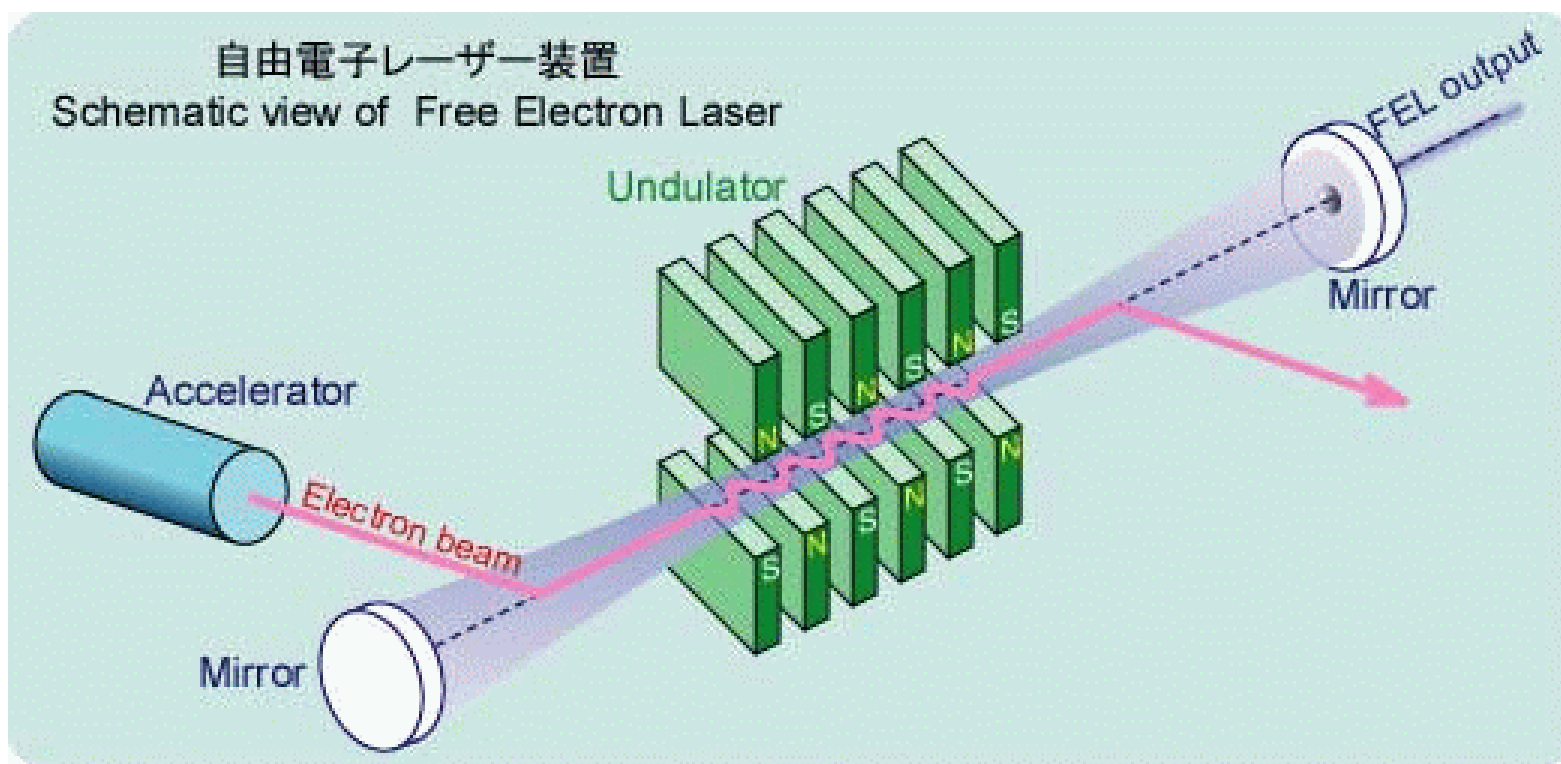


Stability of electron bunch interval and absolute measurement of an optical cavity length at JAERI-FEL

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N. Kikuzawa, M. Sawamura, and E. J. Minehara

JAERI Advanced Photon Research Center
Free Electron Laser group

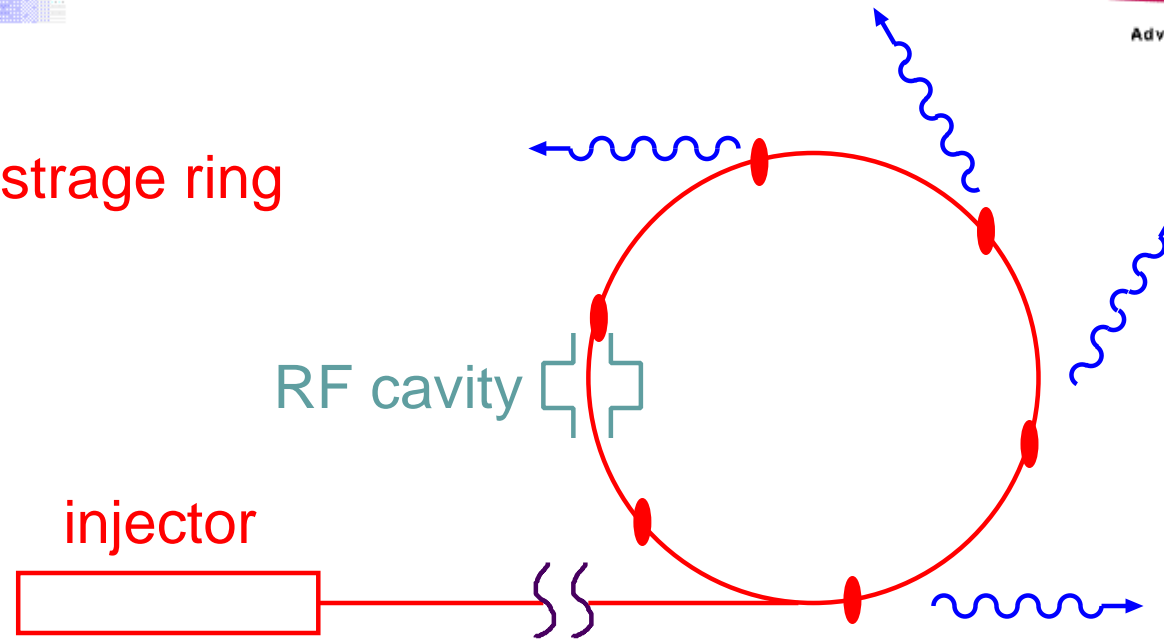
Free Electron Laser oscillator



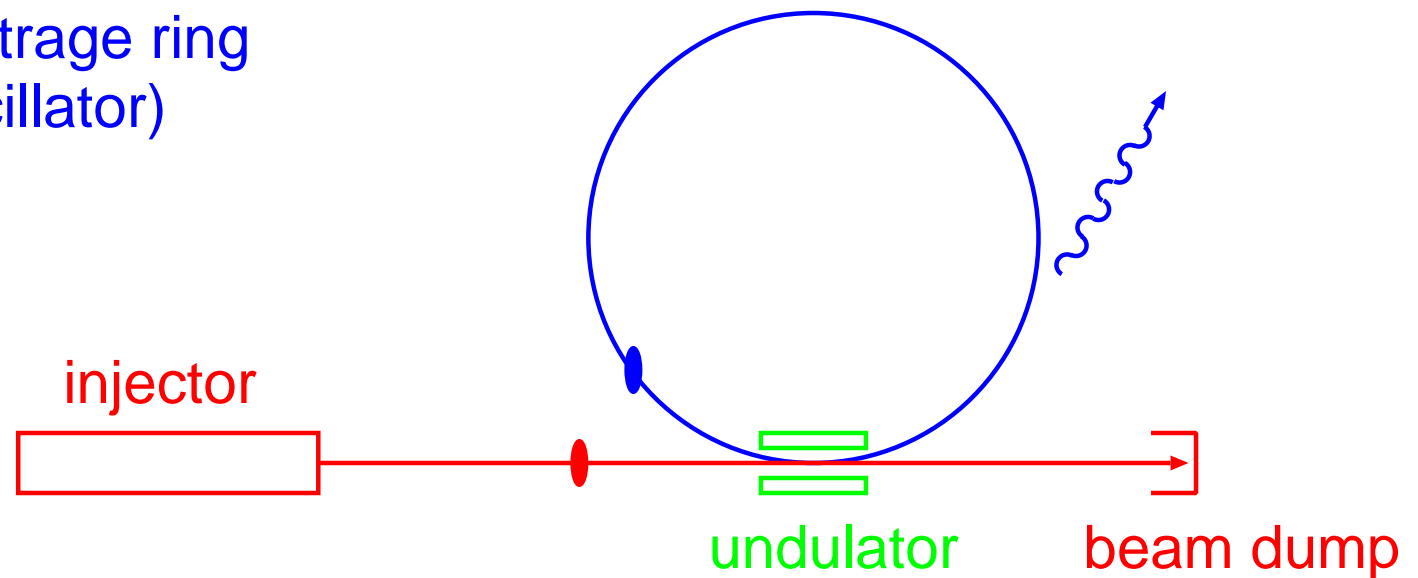
Reference

[1] iFEL "<http://gatekeeper.fel.eng.osaka-u.ac.jp>"

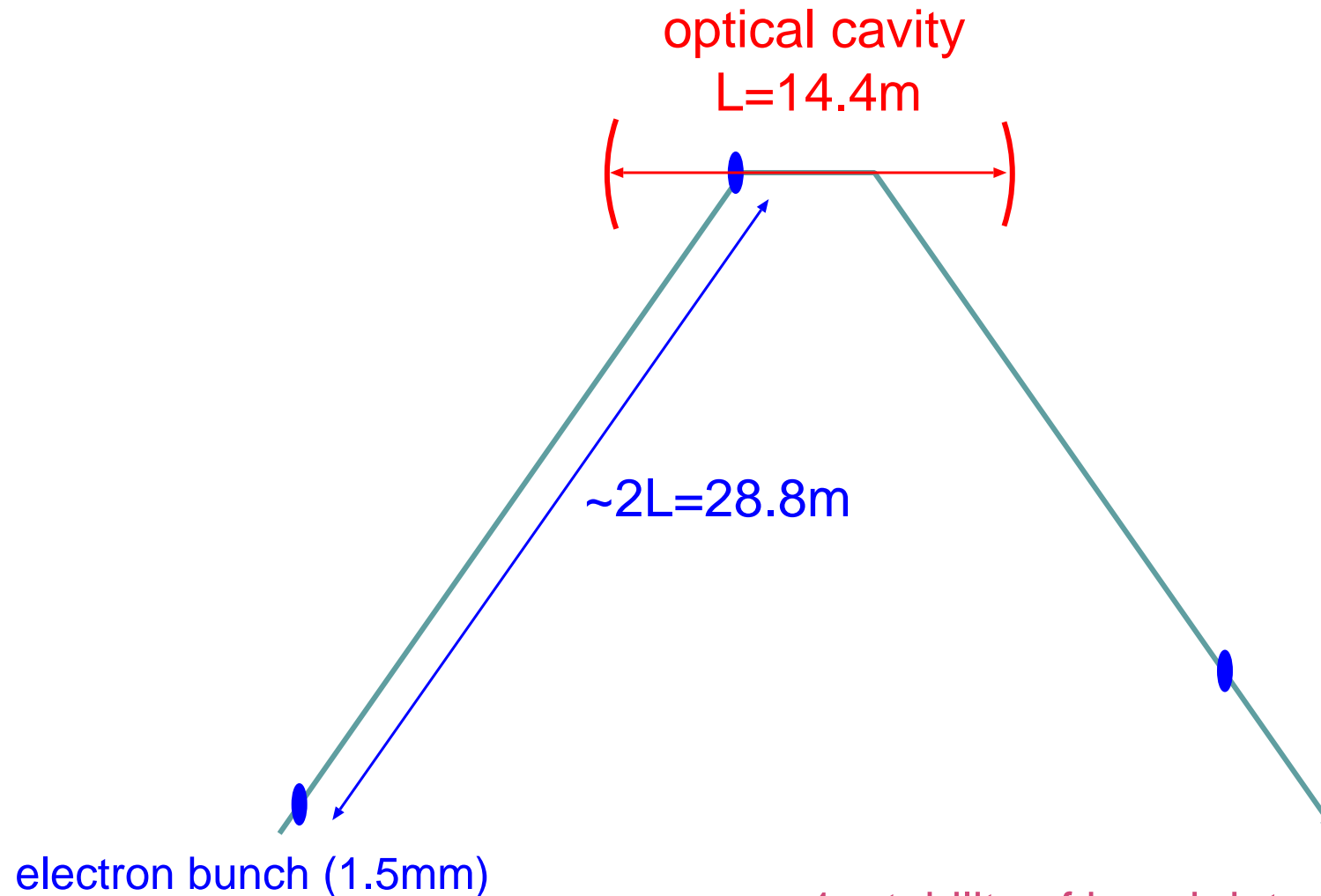
Electron storage ring



Optical storage ring (FEL oscillator)

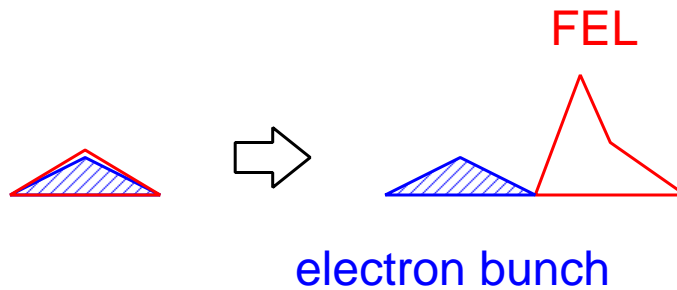


Preconditions required to FEL oscillators

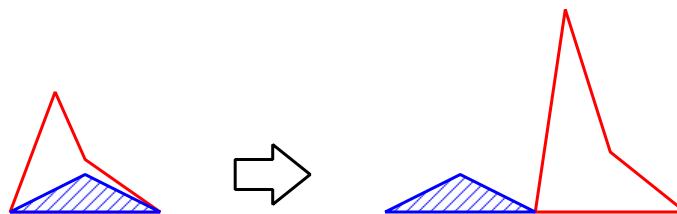


1. stability of bunch intervals
2. cavity length tuned to the bunch interval

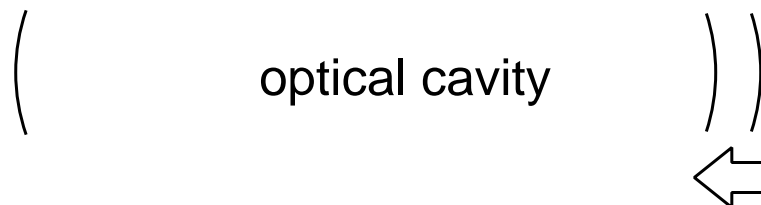
Slippage and laser lethargy



"slippage" = $N w \lambda$



"laser lethargy"
FEL group velocity $< c$

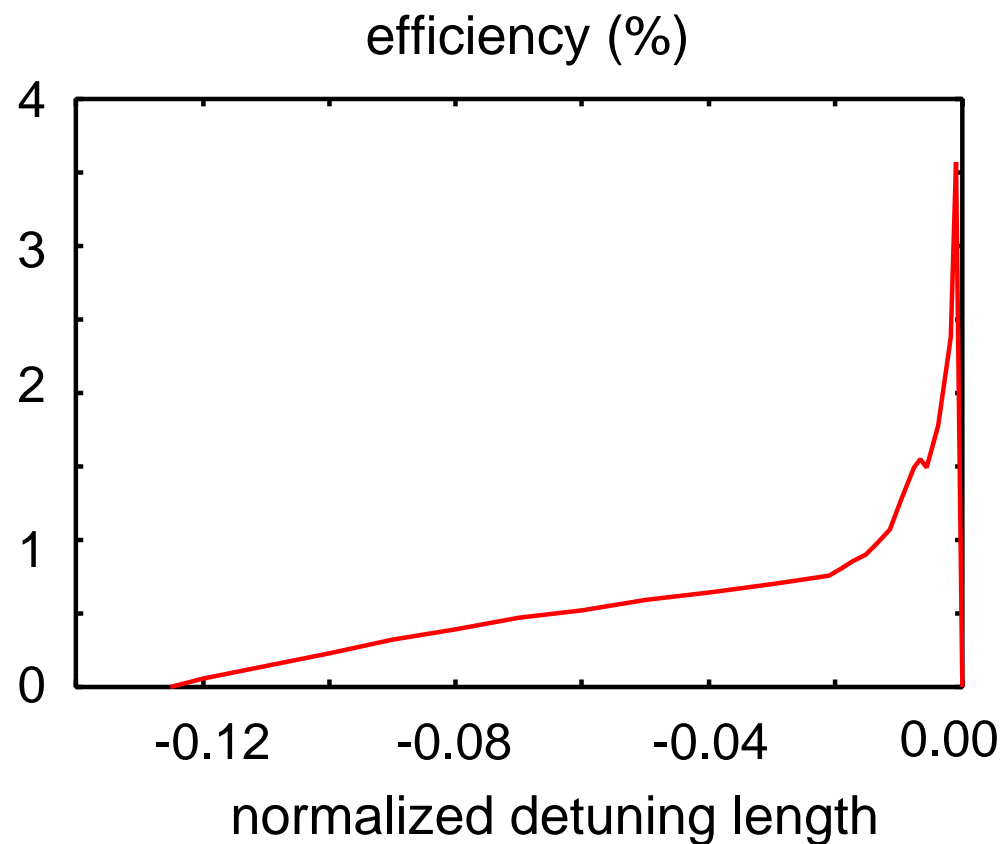
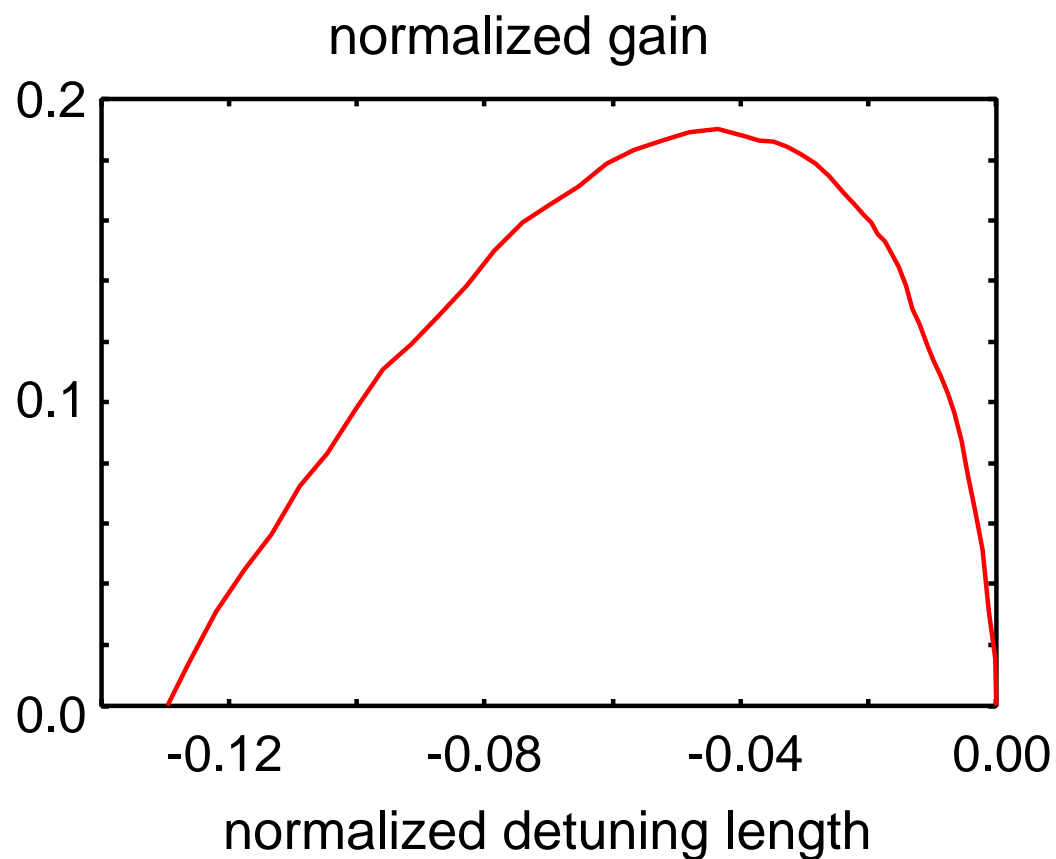


$\delta L < 0$

Reference

[2] W. B. Colson, in Laser Handbook (North Holland, Amsterdam, 1990), Vol.6, pp.176-180

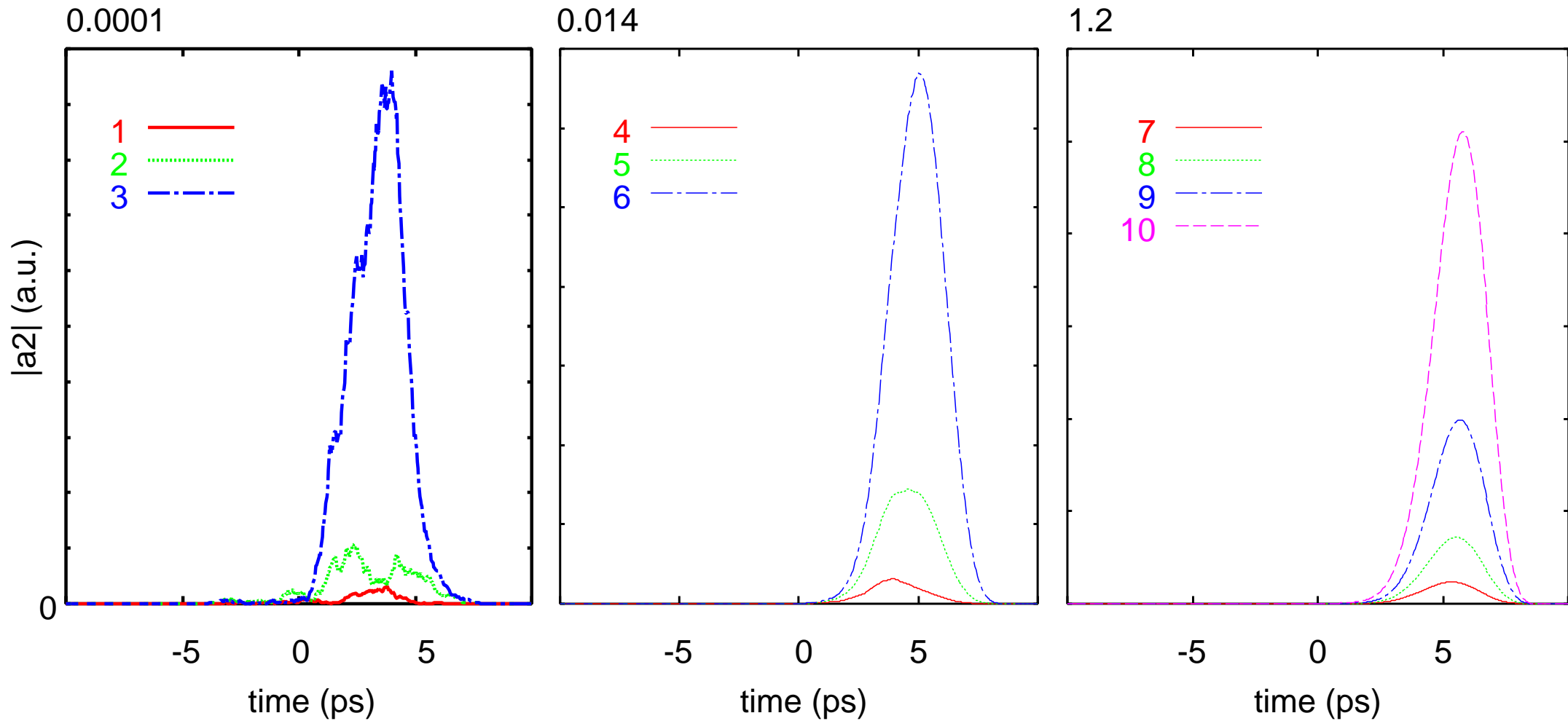
Conventional FEL oscillator theory



Reference

[3] N. Piovella et al., Phys. Rev. E52, 5470 (1995).

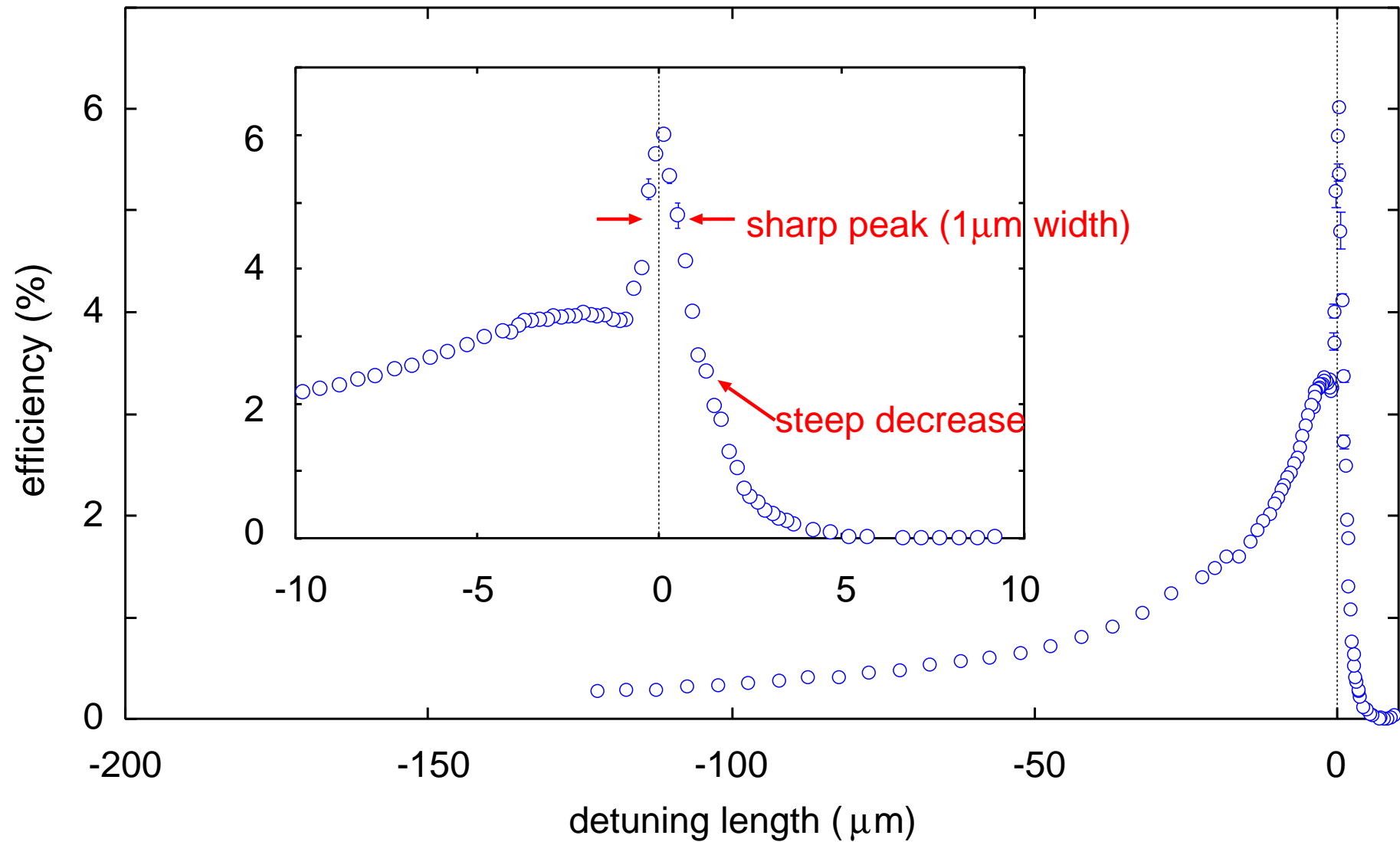
FEL optical pulse evolution with round-trips



Reference

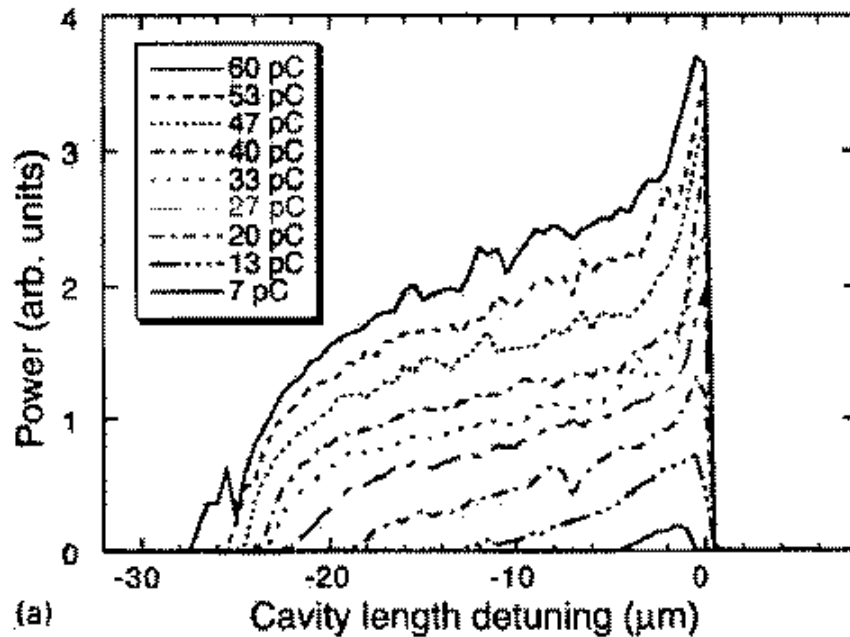
[4] R. Hajima et al., in Proceedings of FEL2001 conference, Darmstadt (2001).

Efficiency detuning curve at JAERI-FEL



Efficiency detuning curve at other laboratories

J lab [5] low jitter



LANL [6] 10ps jitter

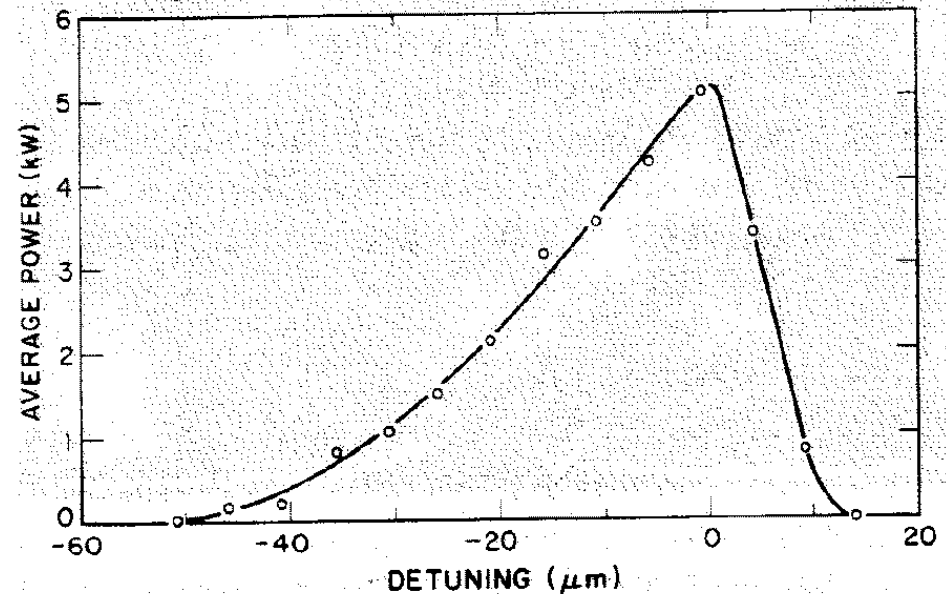


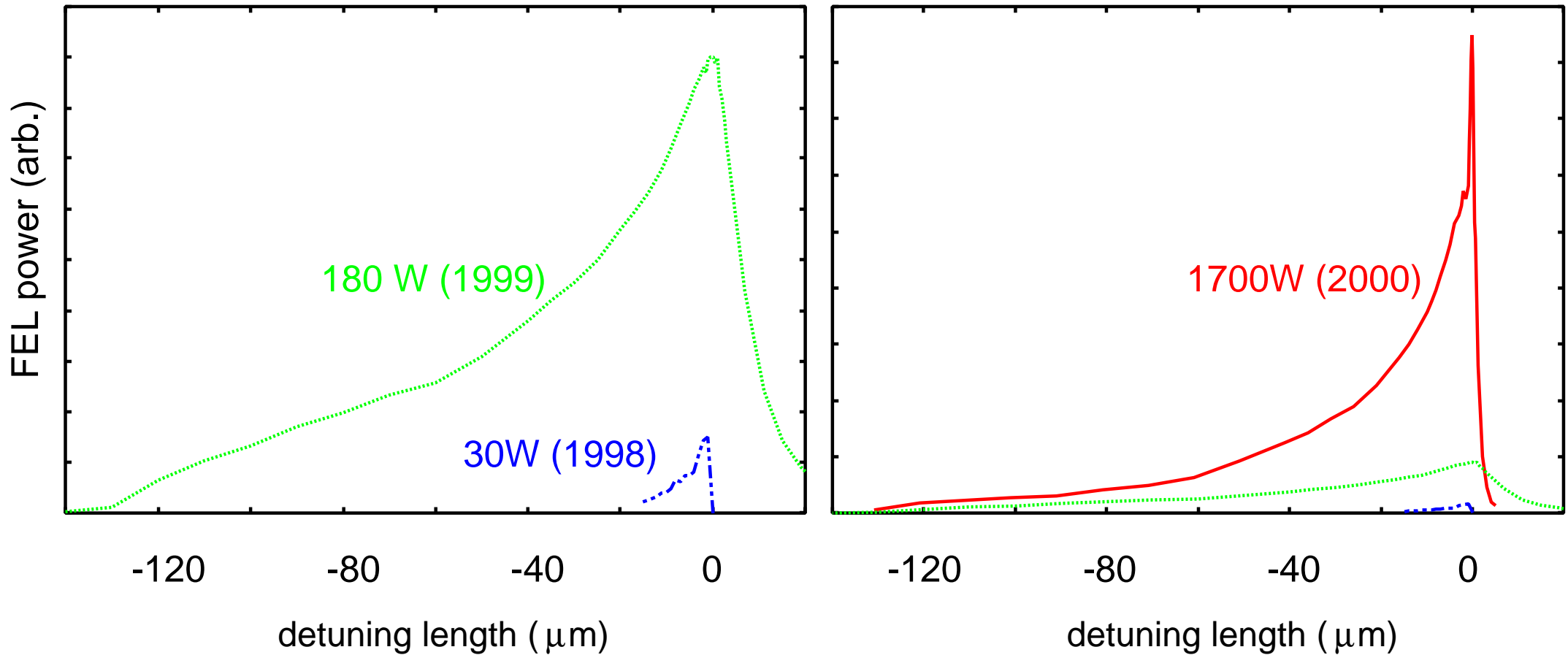
Fig. 9. Resonator cavity-length detuning dependence. Negative lengths indicate short cavity.

Reference

[5] S. Benson et al., NIM A429, 27 (1999).

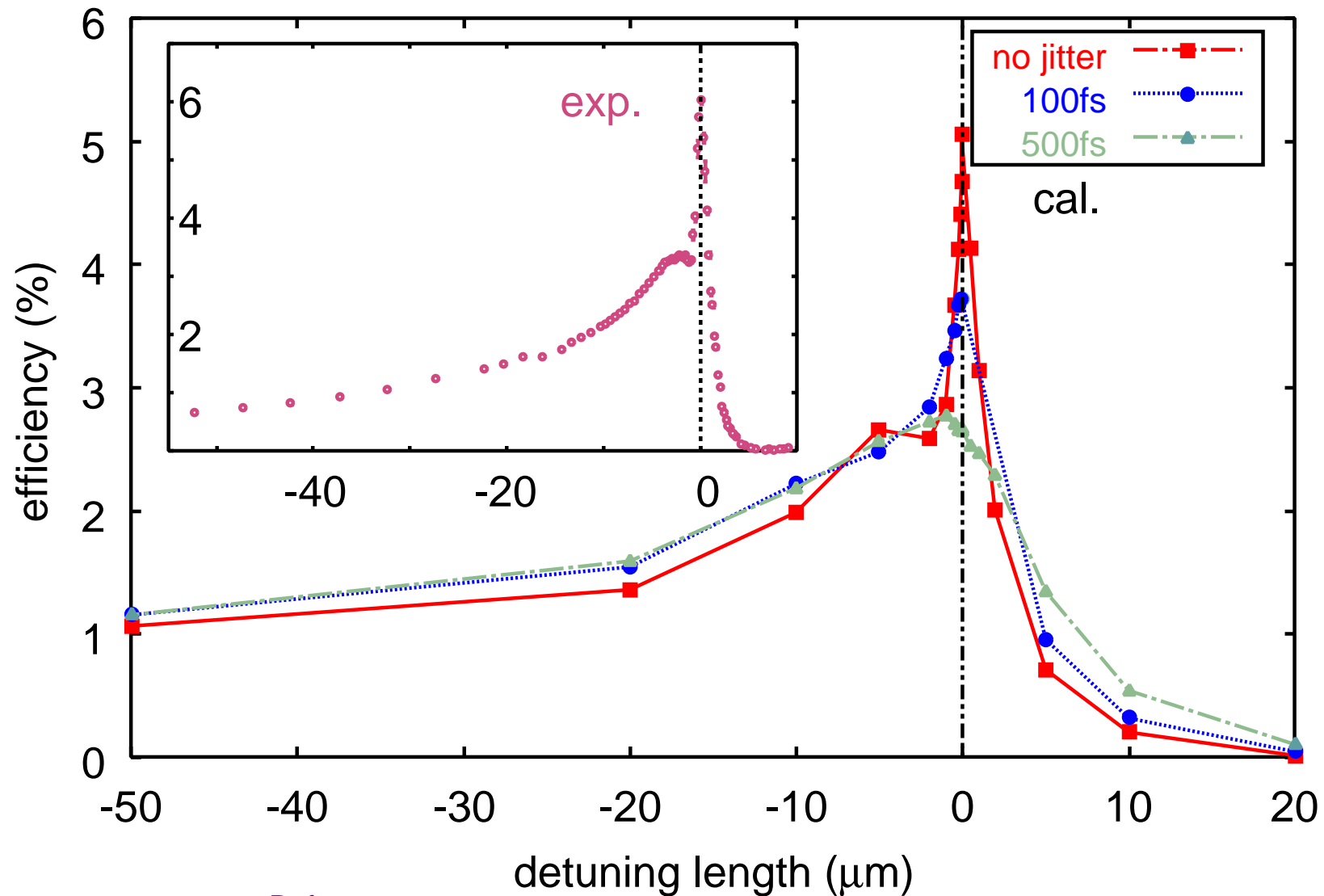
[6] B. E. Newnam et al., NIM A237, 187 (1985), R. W. Warren et al., NIM A237, 180 (1985).

Efficiency detuning curves at JAERI-FEL



Reduction of time jitter and high peak current are necessary for high power FEL operation.

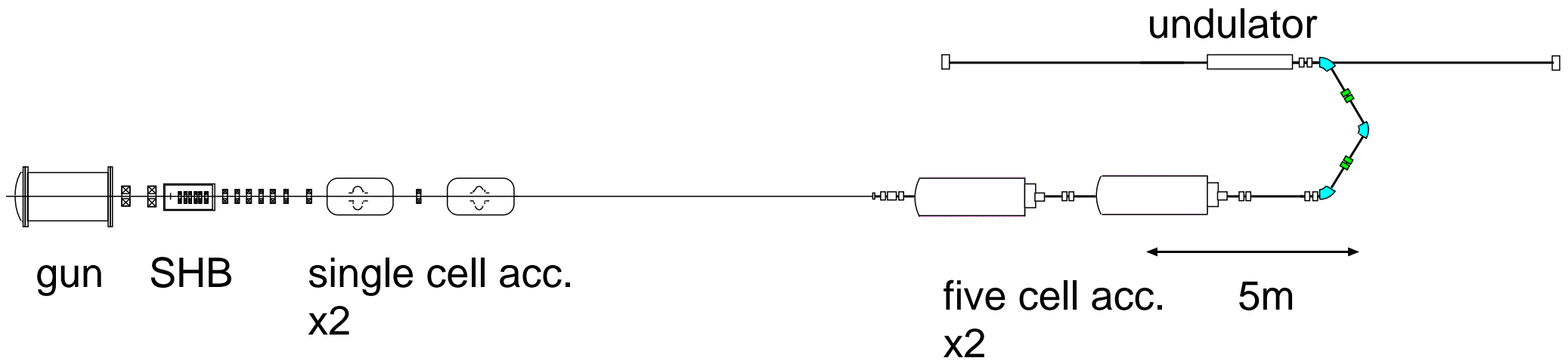
Jitter effect on detuning curve at JAERI-FEL



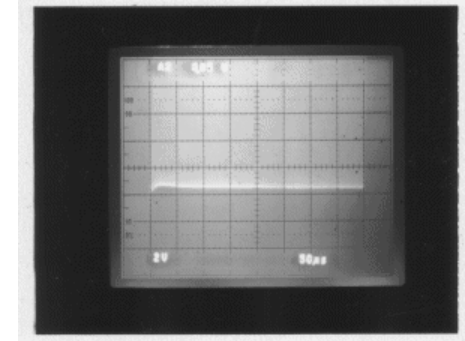
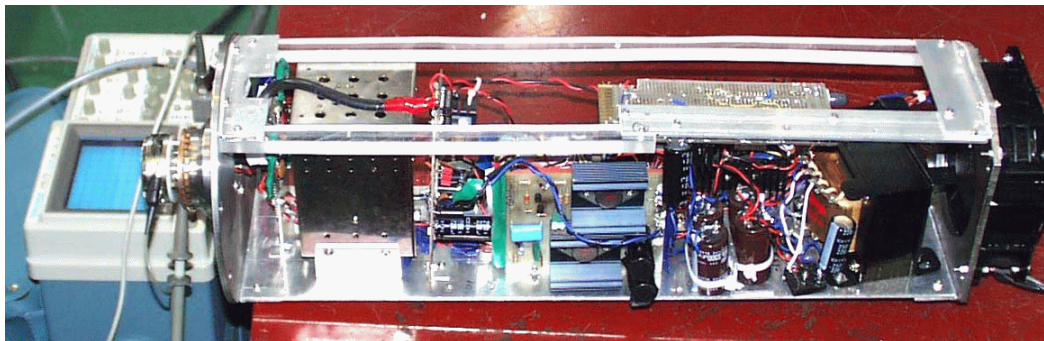
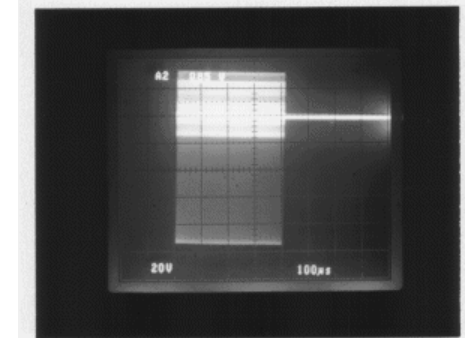
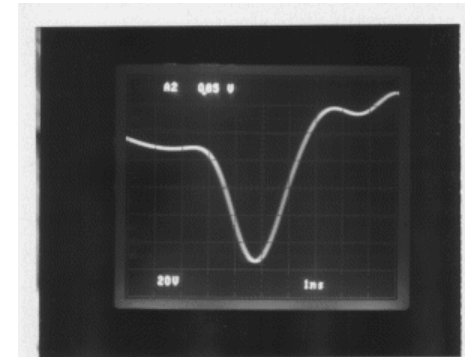
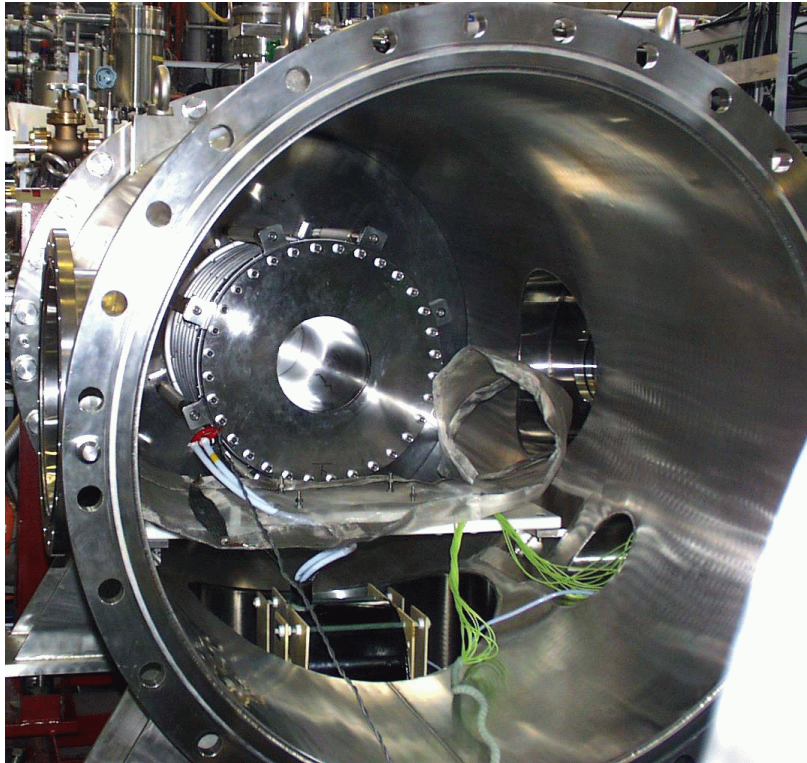
Reference

[7] R. Hajima et al., in Proceedings of FEL2000 conference, Duke (2000).

Layout of JAERI FEL oscillator system

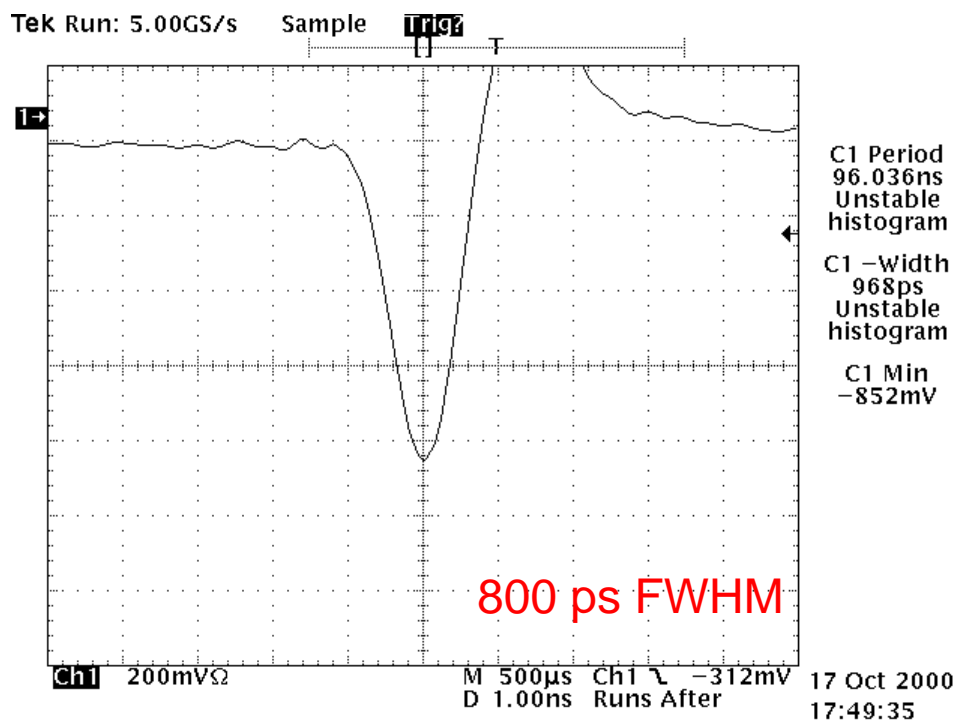


Thermionic cathode gun driven by a grid-pulsar

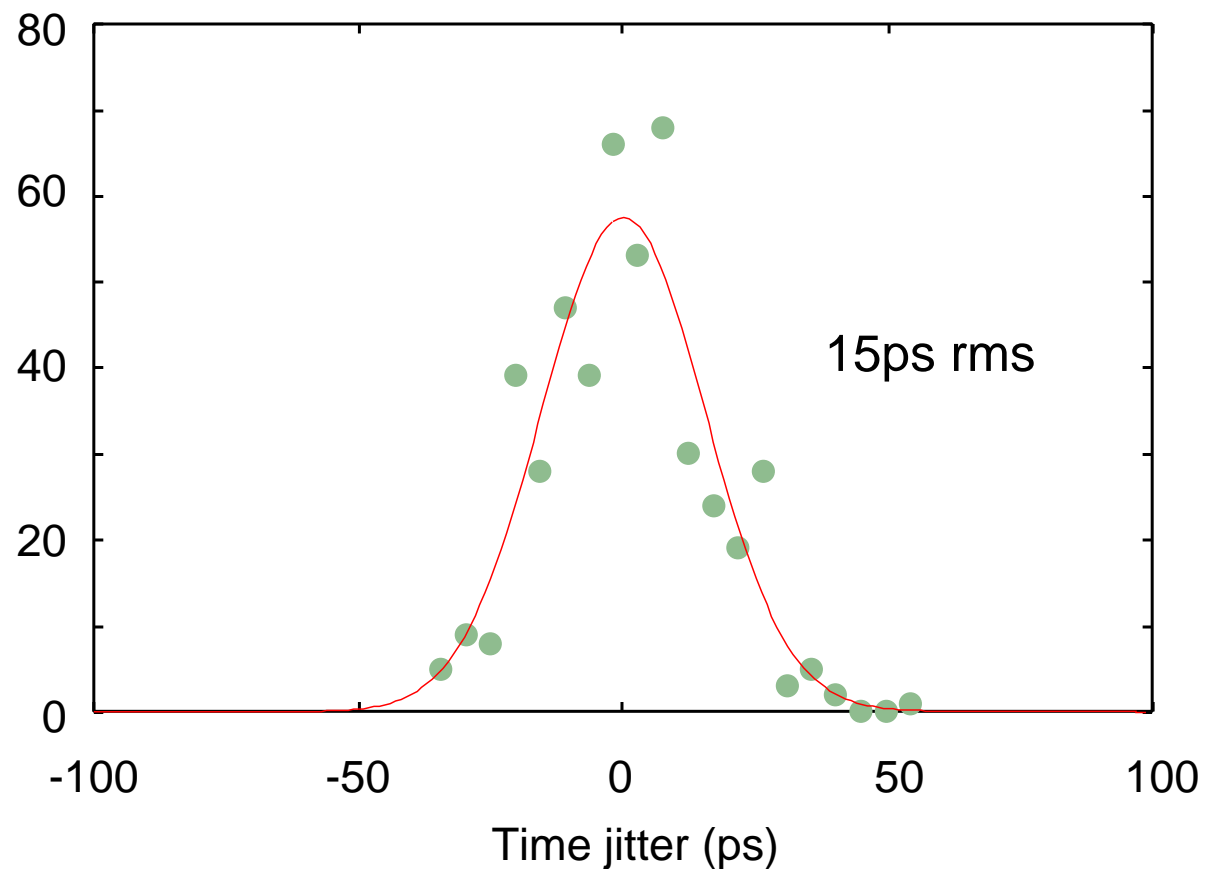


Time jitter at the electron gun

core monitor signal



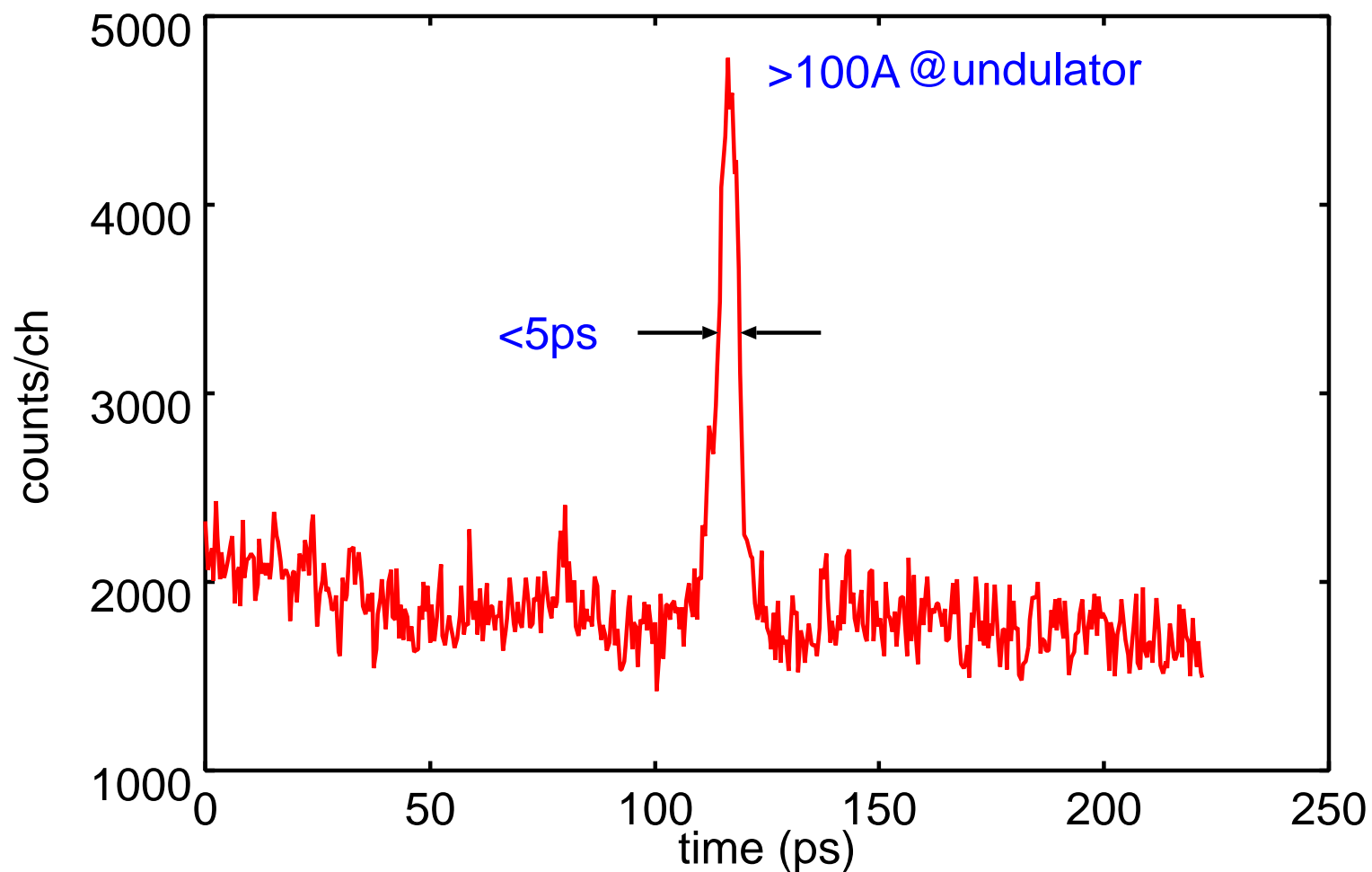
histogram of bunch intervals



Reference

[8] N. Nishimori et al., Proceedings of EPAC2000, Vienna (2000), p1672.

Estimation of time jitter at the undulator

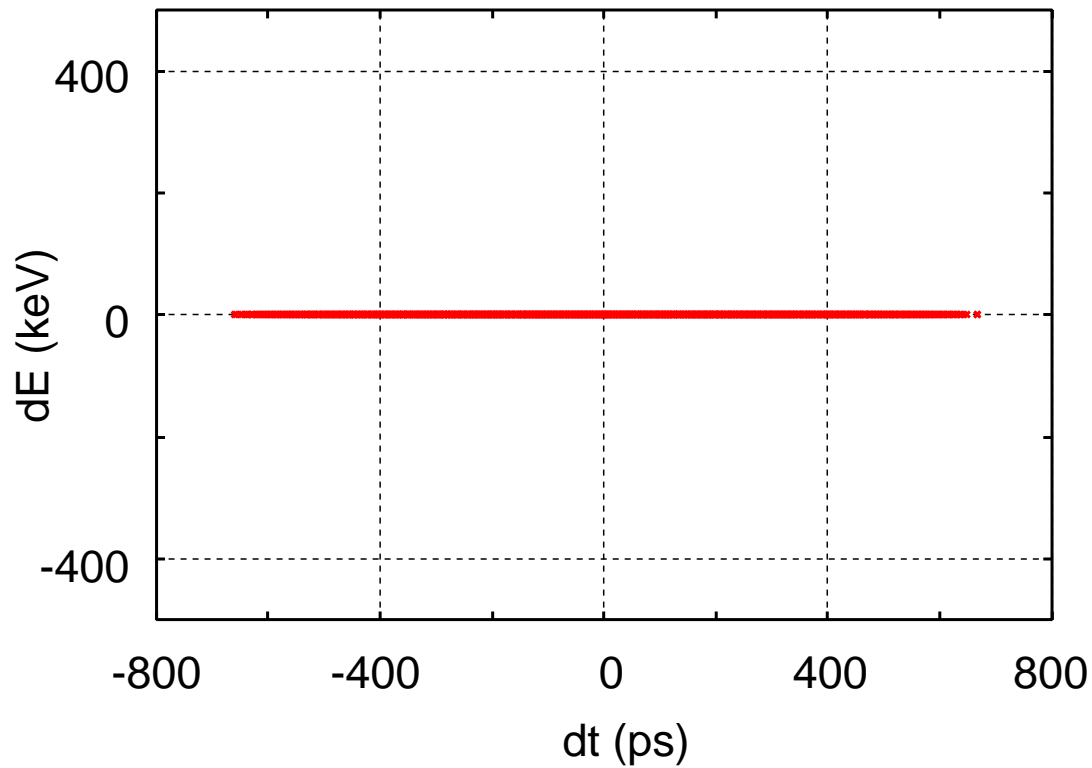


Bunch length
800ps -> 4ps

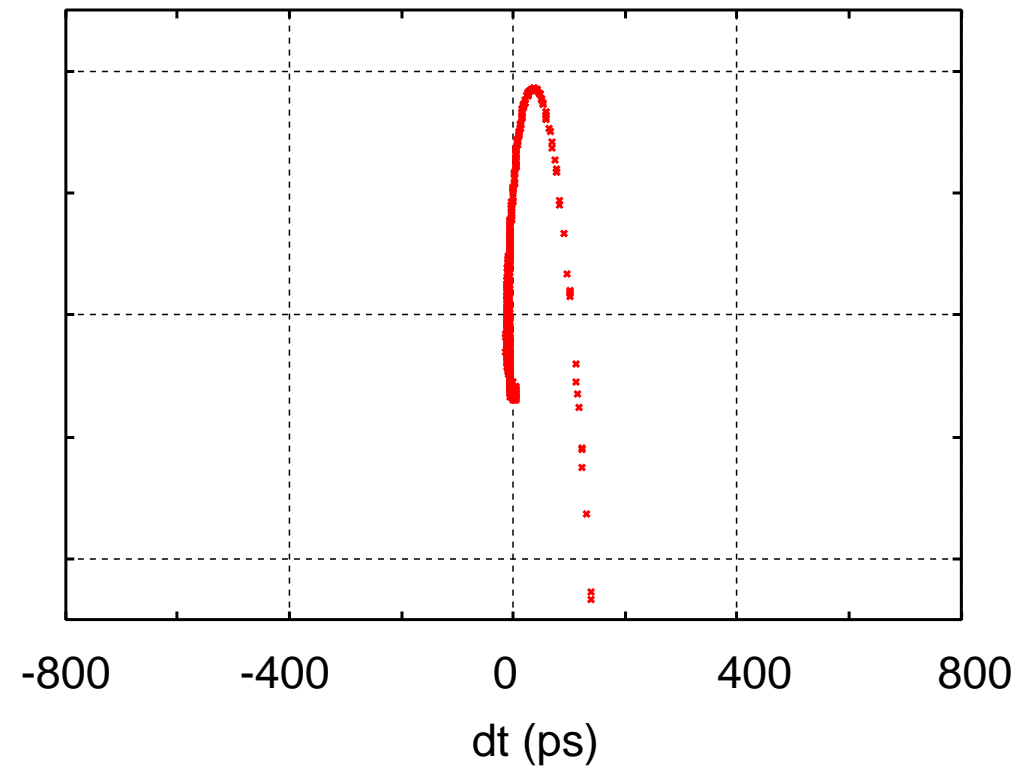
Time Jitter
15ps -> 75fs

PARMELA result

at gun exit

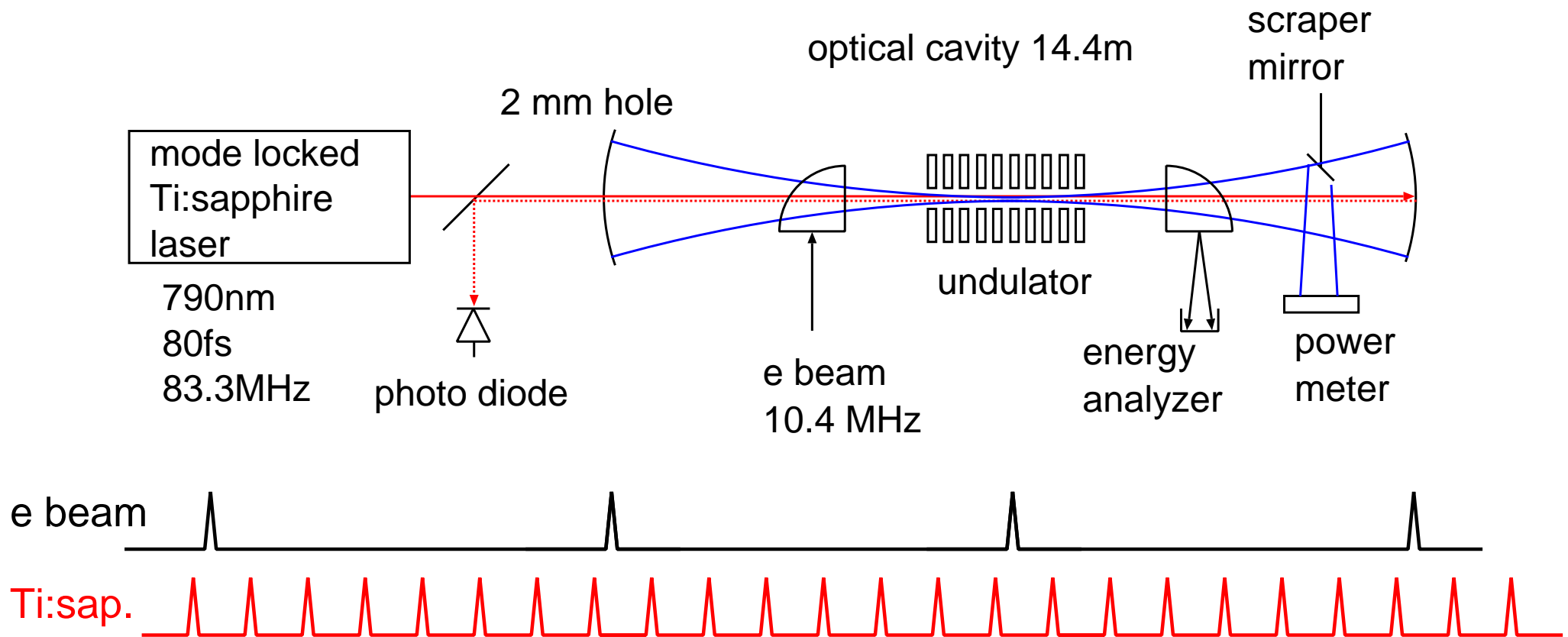


at undulator



We think that the time jitter is much smaller than 75fs, because the jitter at the gun does not affect the jitter at the undulator directly.

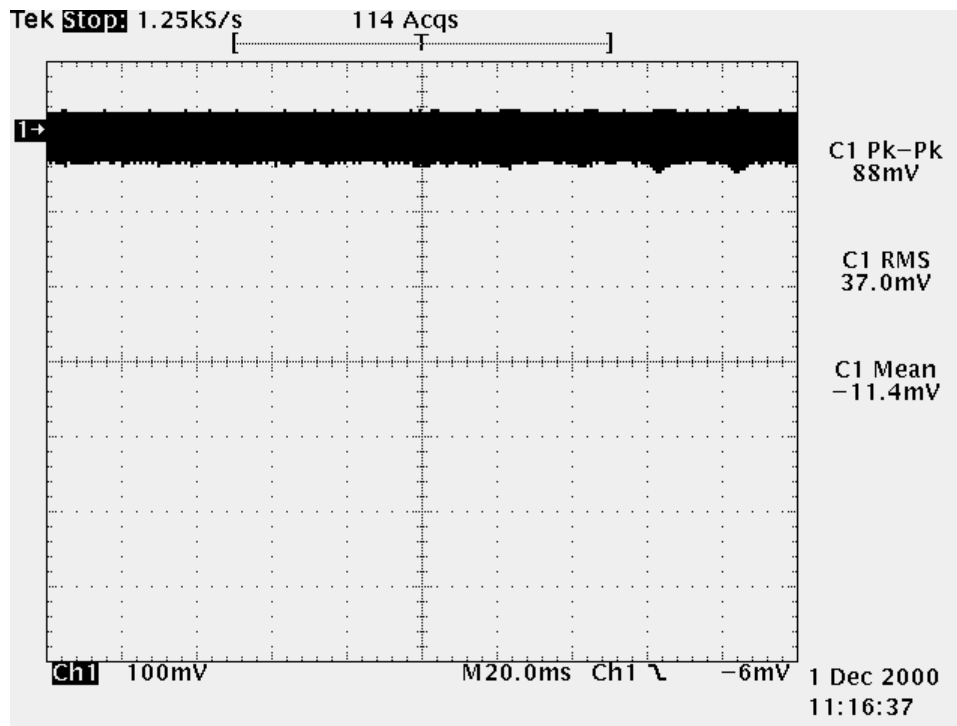
Experimental setup for measurement of optical cavity length



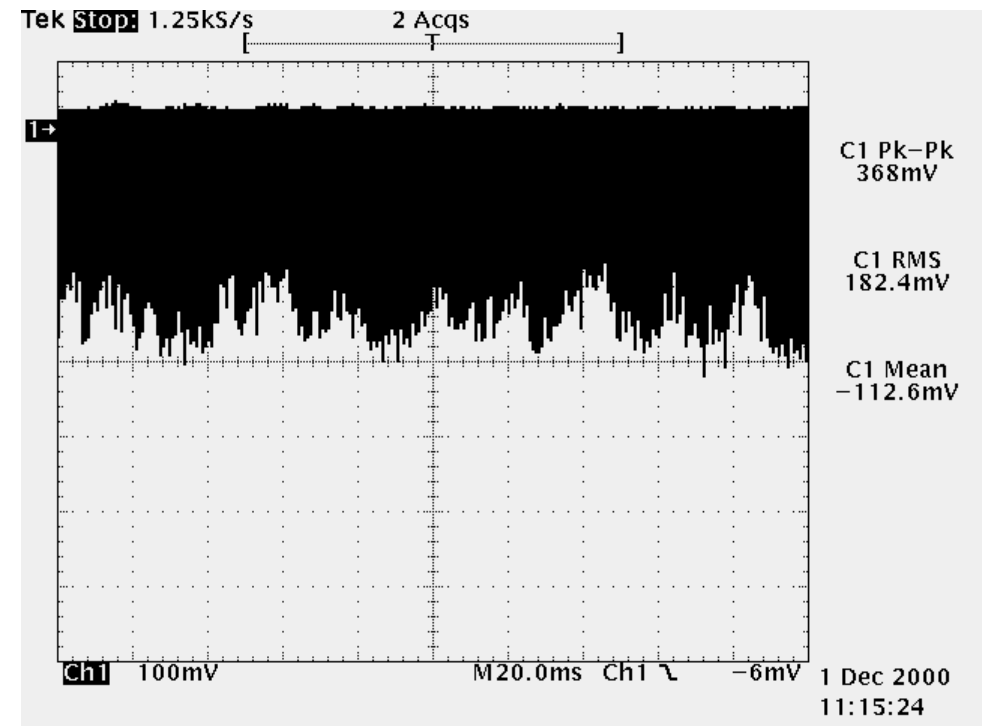
Reference

- [9] P. Haar, H. A. Schwettman, and T. I. Smith, NIM A358, 319 (1995).
- [10] K. W. Berryman, P. Haar, and B. A. Richman, NIM A358, 260 (1995).
- [11] N. Nishimori et al., Rev. Sci. Instrum. 69, 327 (1998).

Photo diode signal

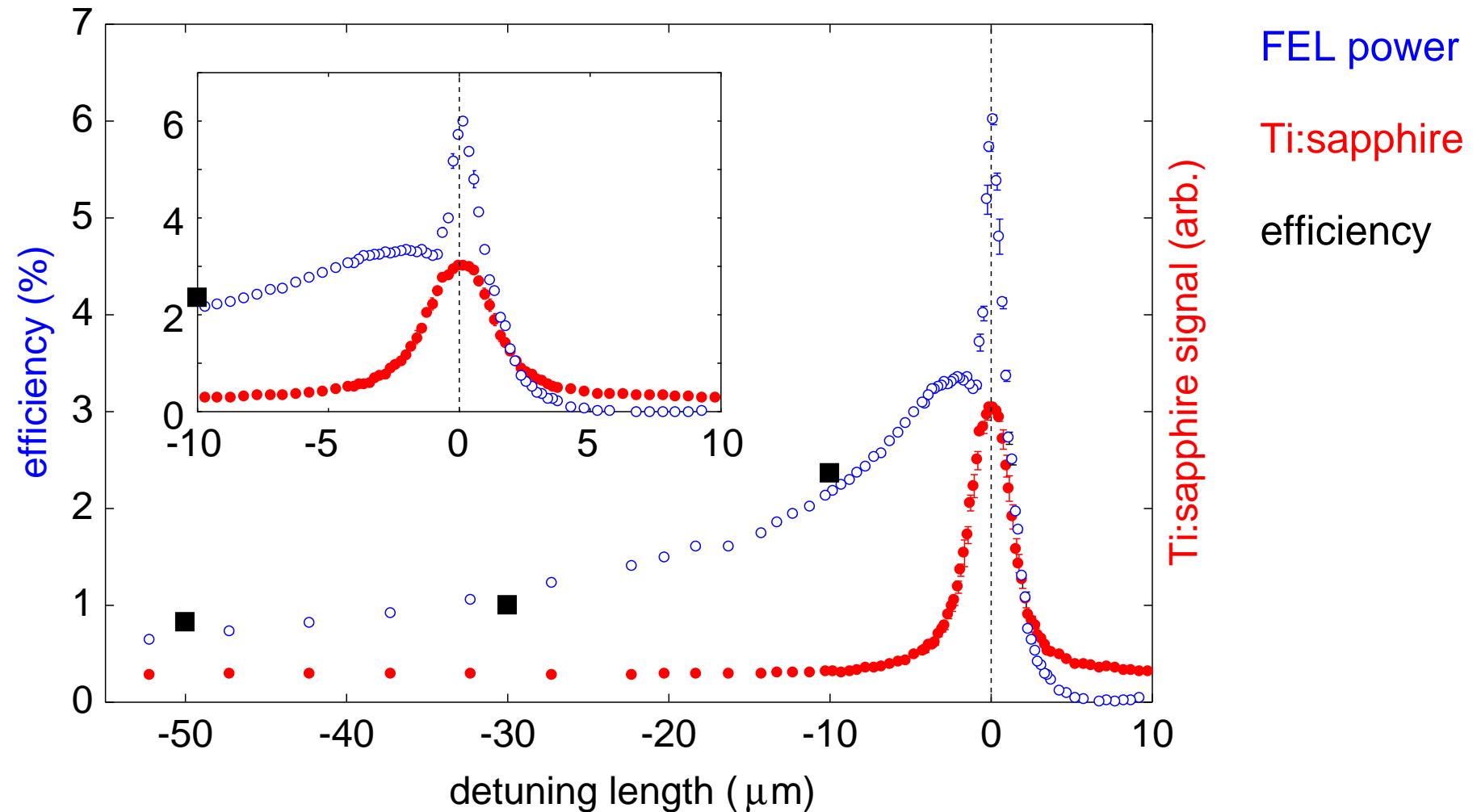


off resonance



on resonance

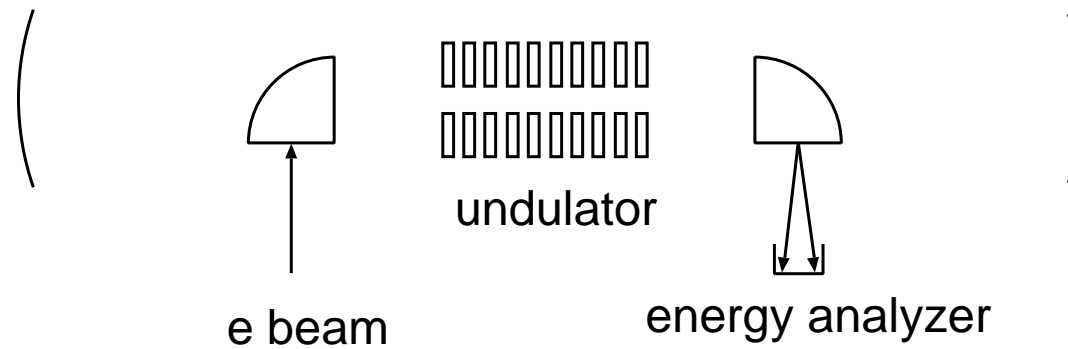
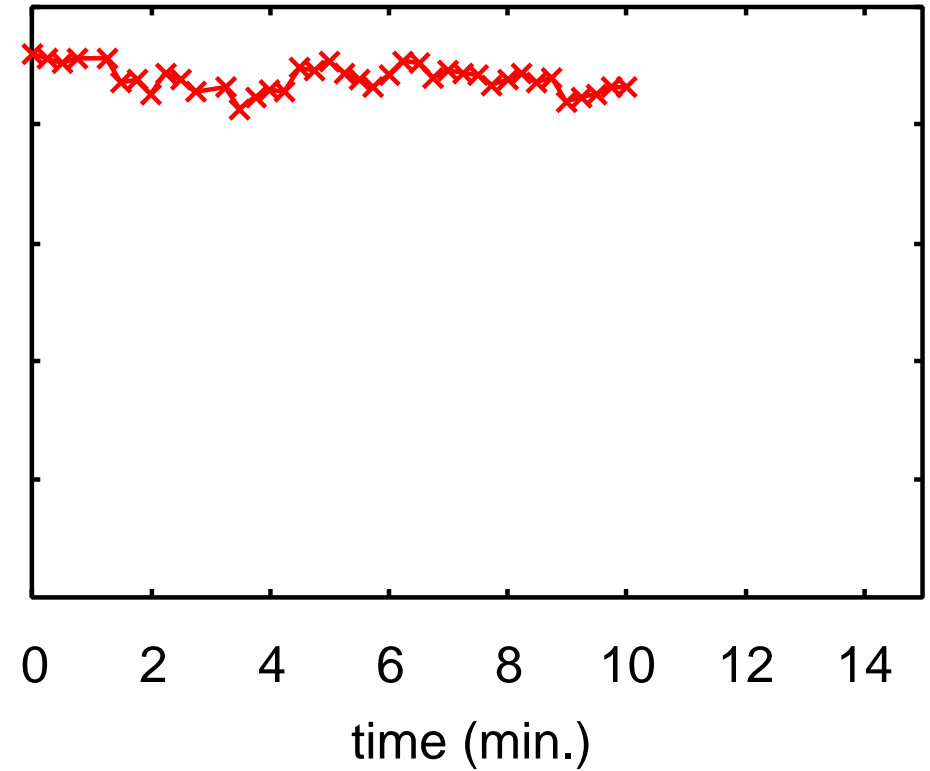
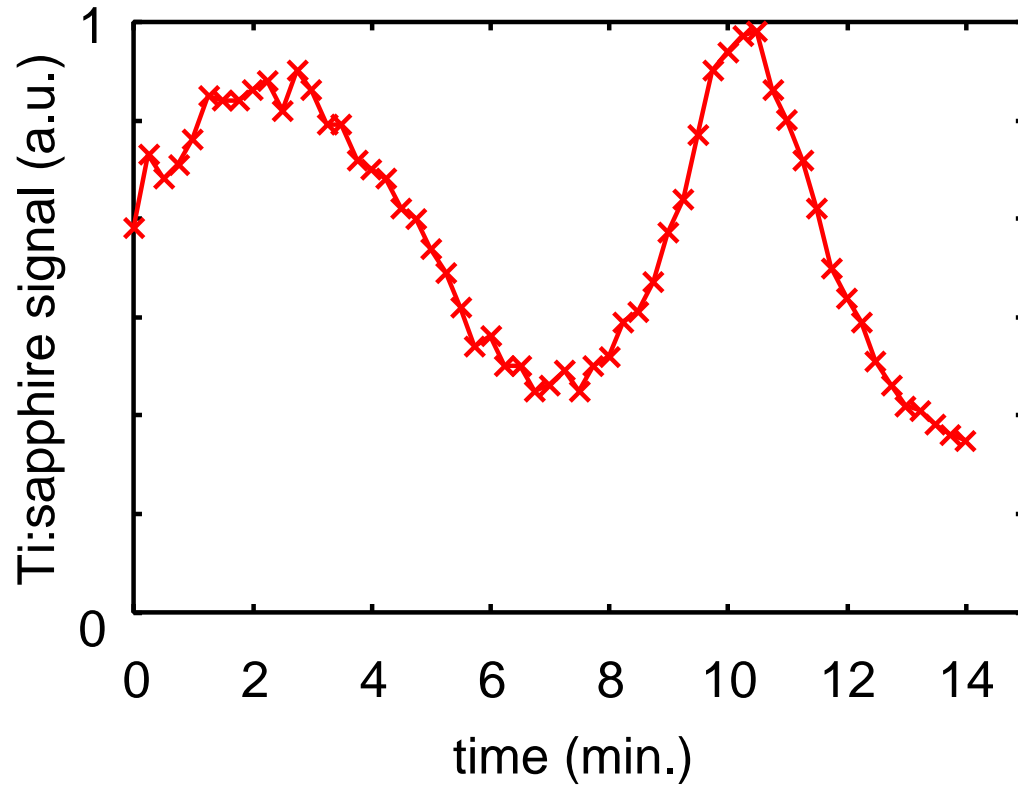
Experimental result



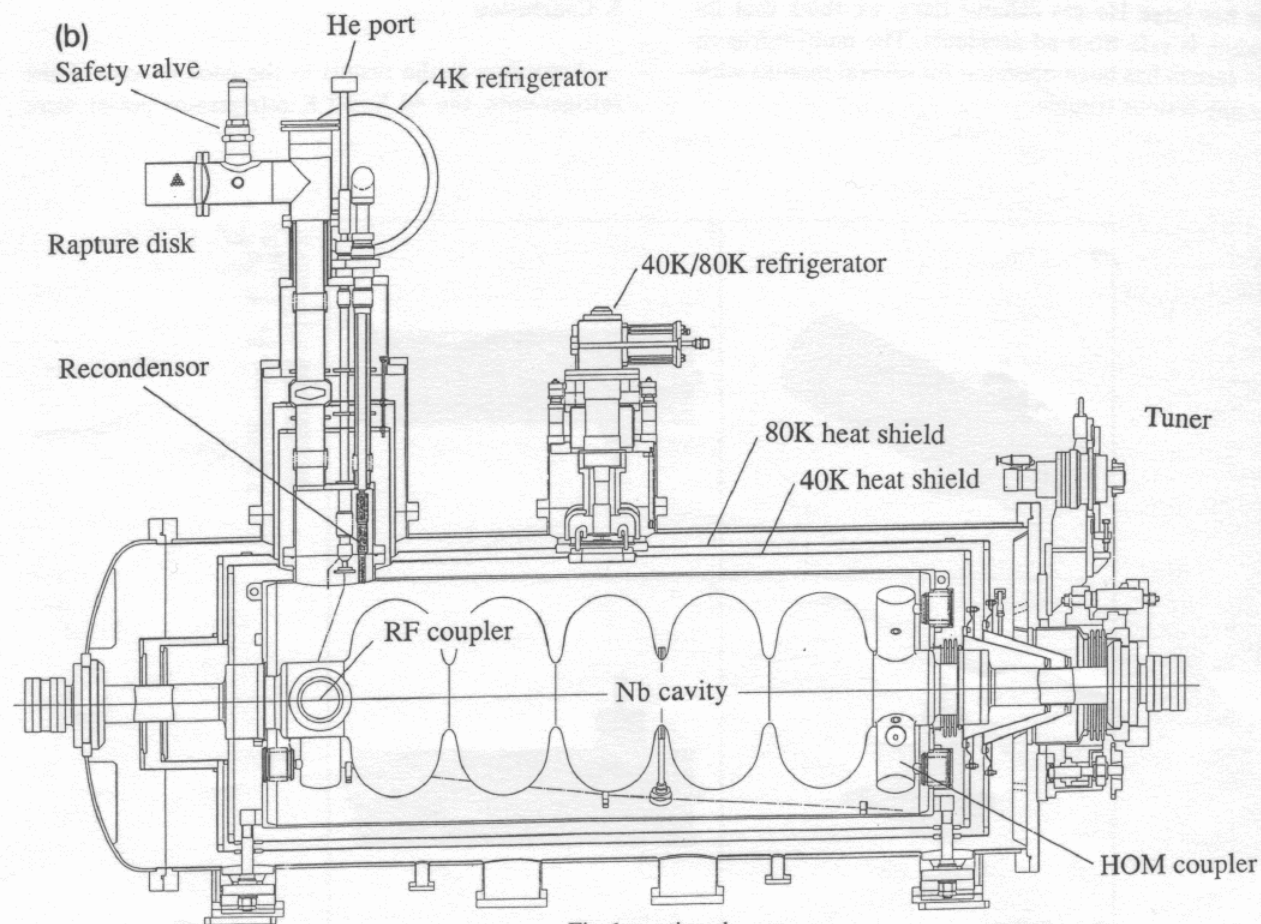
Reference

[12] N. Nishimori, R. Hajima, R. Nagai, and E. J. Minehara, Phys. Rev. Lett. 86, 5707 (2001).

Stability of cavity length



Vibration of RF coupler (~1Hz)



In order to reduce fluctuation in a long time range ...

1. Reduction of RF coupler vibration
2. Stabilization of optical cavity length within $0.1 \mu\text{m}$
3. Stabilization of amplitudes and phases of RF systems
4.

Conclusion

- An FEL oscillator is a similar device to a synchrotron radiation source, but must satisfy some preconditions for the full performance :stability of bunch intervals in a macropulse and high longitudinal brightness.
- The above requirements have been satisfied in JAERI-FEL facility: time jitter less than 75 fs rms in an undulator and peak current higher than 100 A. These improvements directly led to high FEL efficiency operation in JAERI-FEL.
- Our next task is reduction of long time range fluctuation in order to provide stable FEL light like synchrotron radiation sources.

エネルギー回収型リニアック鳥瞰イメージ

