

June 26, 2004

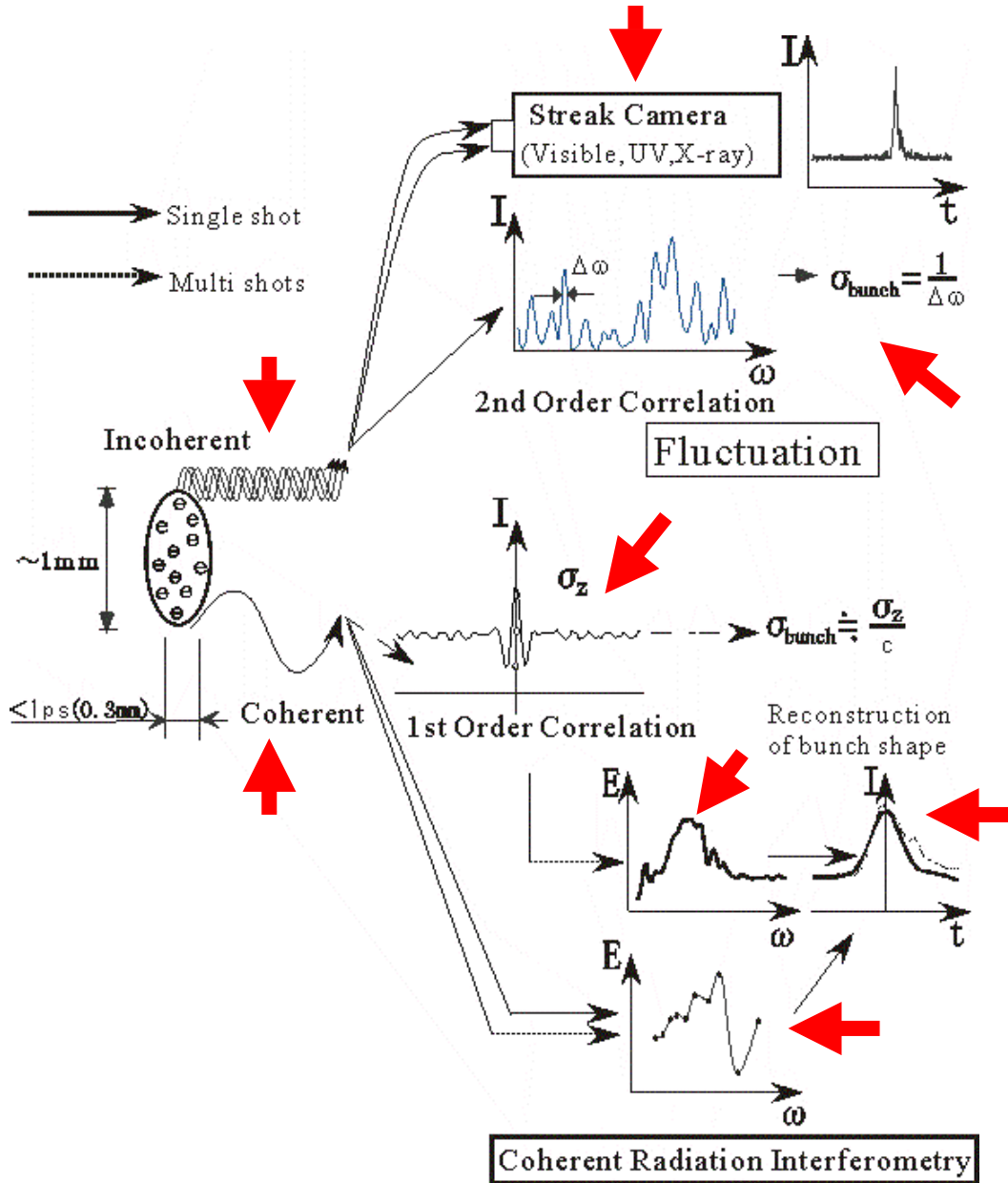
International Symposium on  
Ultrafast Accelerators for Pulse Radiolysis

# Pulse width measurement and control

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# Femtosecond Electron Bunch Diagnostics



**Incoherent Radiation**

**Streak Camera**

**Fluctuation Method**

**2nd Order Correlation**

**Bunch Form Factor**

**Bunch Shape**

**Coherent Radiation**

**1st Order Correlation**

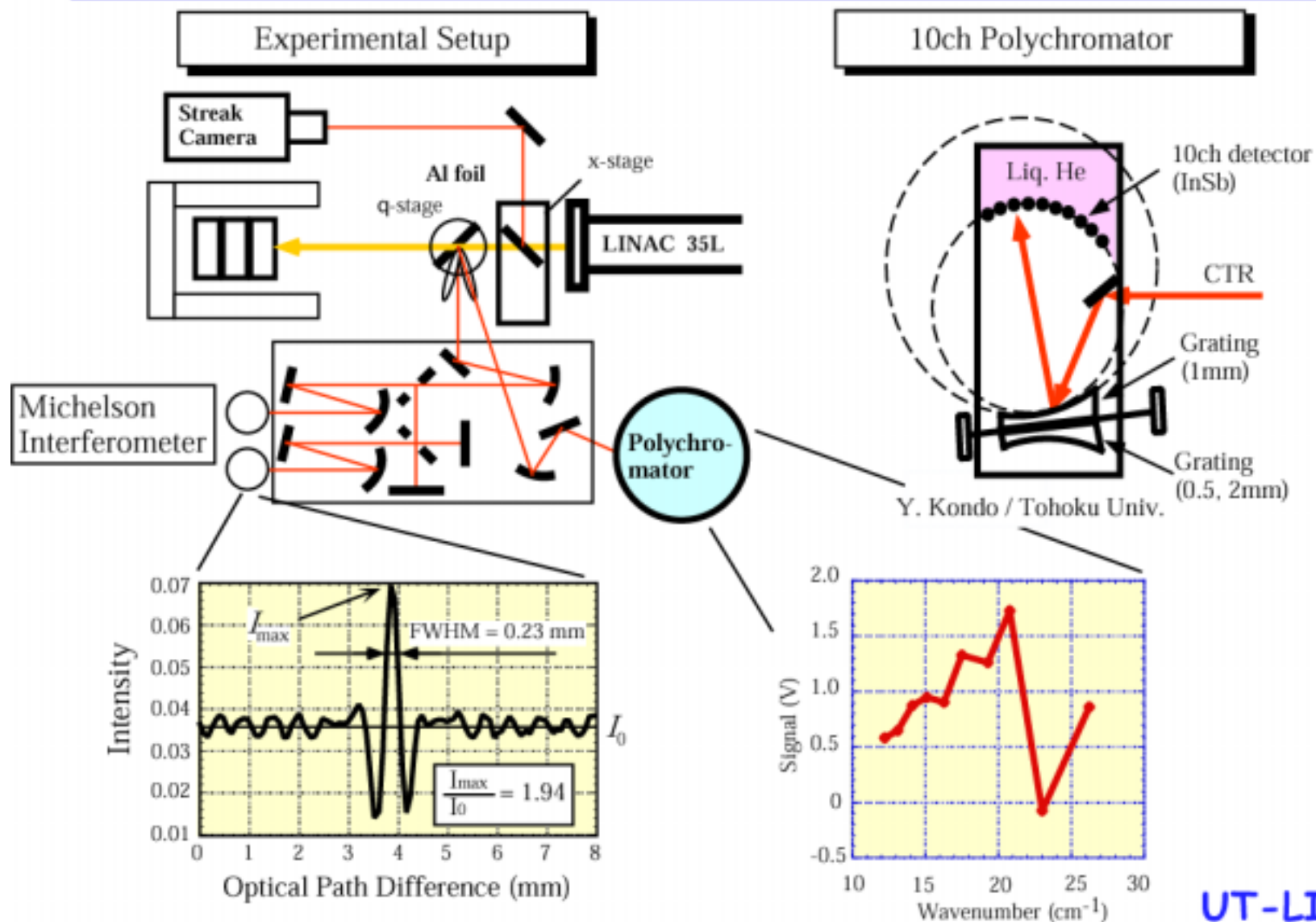
or

**Single-shot Acquisition of Spectrum**

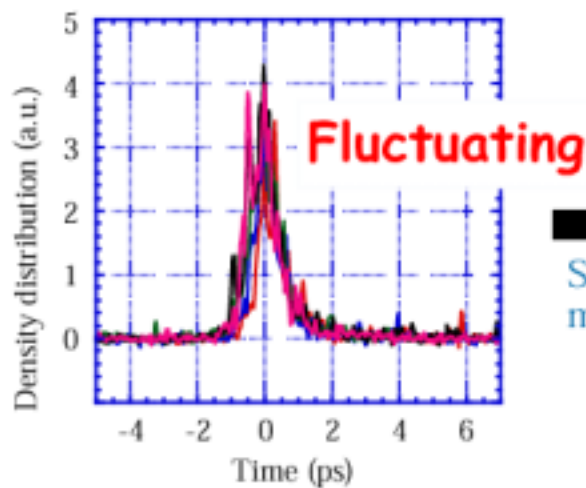
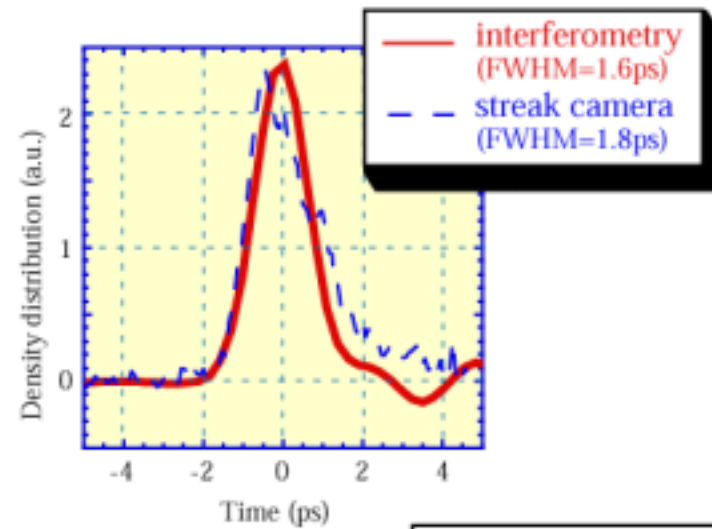
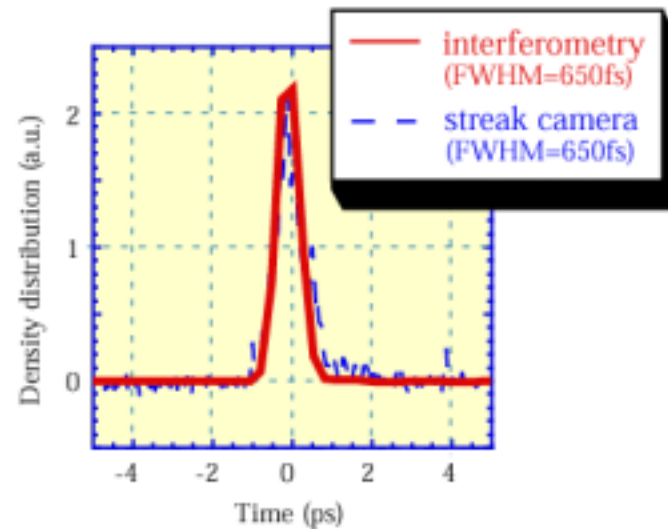
**Bunch Form Factor**

**Bunch Shape**

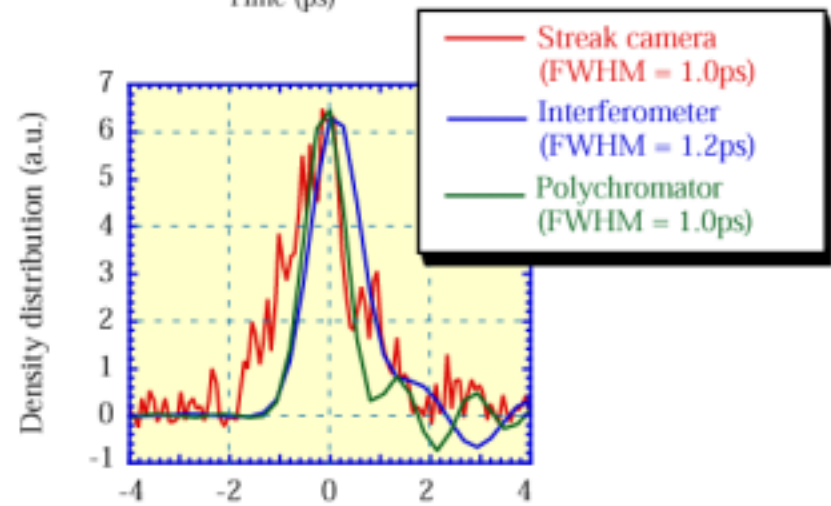
# Measurement using coherent radiation



## Bunch distribution from interferogram

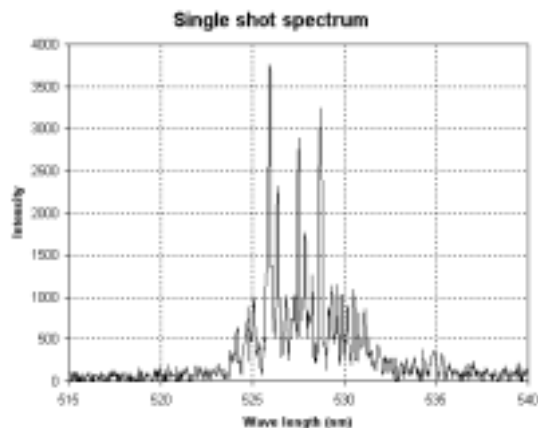


Single-shot measurement

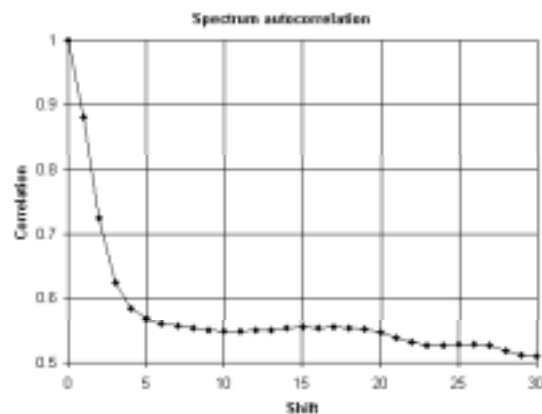
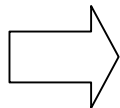


Good agreement within 20% error could be obtained, but...

# Bunch Length Measurement by Fluctuation Method(ANL)



Example of the single-shot spectrum



Autocorrelation of the spectrum  
Horizontal axis : pixel size of the CCD  
(1pix=  $2.4 \times 10^{11}$  rad/s)

Measure the spectrum of the incoherent radiation



The width of the spike is corresponds to the pulse width  $\sigma_t \sim 1/2\delta\omega$



Pulse width  $\sim 4.5$  ps (FWHM)

# Past / Present /Future of Streak Measurement

- Space charge effects limit the time resolution.



Low Accel. Voltage



High Accel. Voltage

B.E.Carlsten et al., Micro bunches workshop (1995) p21



C4575-01

(Hamamatsu Photonics)

10 kV/1.6mm

Resolution: ~ ps

Sweep velocity on the Phosphor  
28mm/0.1ns ( $2.8 \times 10^8$  m/s)

Accelerator Voltage: High

Time resolution: Low

Higher Voltage  
to suppress  
space charge force

Under development



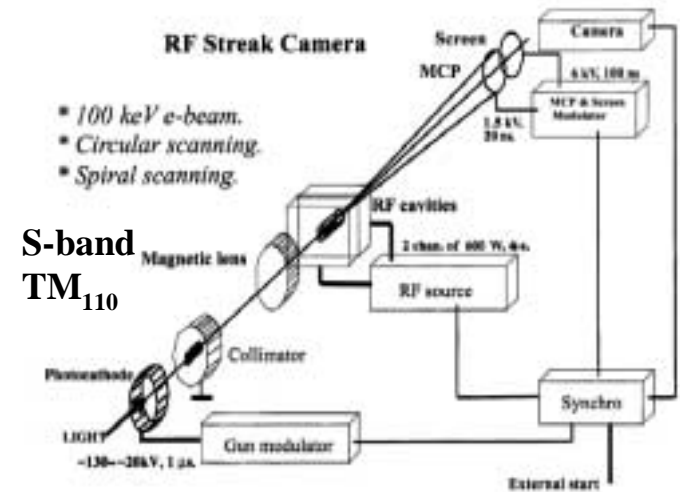
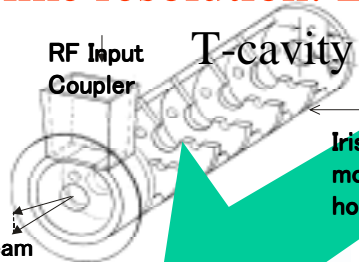
FESCA200 (Hamamatsu Photonics)

15 kV/1.6mm

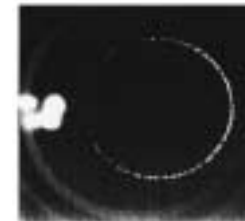
Resolution: ~200 fs

Sweep velocity on the Phosphor

10mm/20ps ( $5 \times 10^8$  m/s)



Radio Frequency based streak camera.



A.V. Aleksandrov et al.

RSI 70 (1999) 2622.

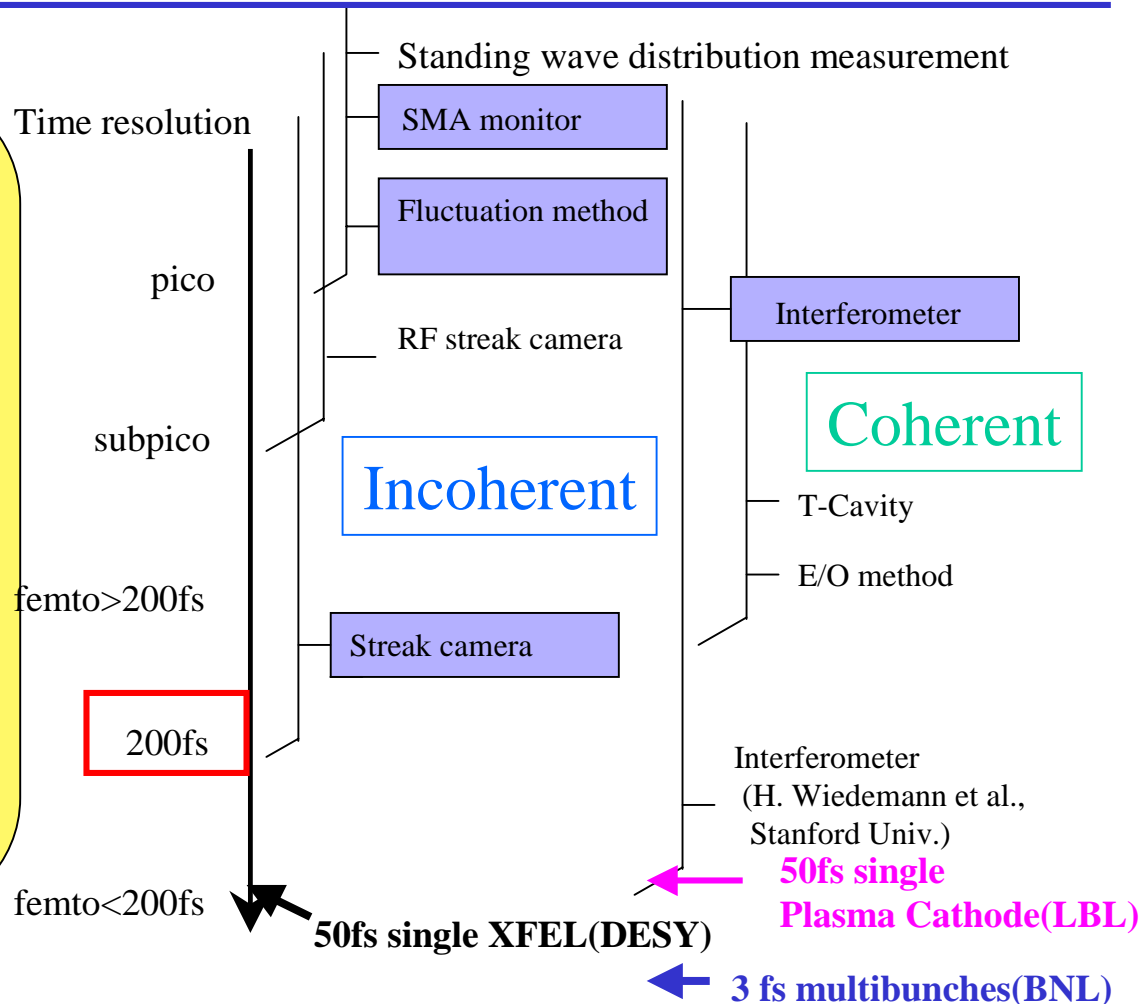
P.Bak et al.,  
Laser Part. Beam  
19(2001) 105.

50 fs resolved Camera and Attosecond Streak Camera  
(Hamamatsu Photonics/ U. Tokyo)

# Methodology and Resolution of Pulse Length Measurement

**Bunch length measurement method**

- Radiation techniques
  - Streak camera
  - Interferometer
  - Fluctuation method
- RF techniques
  - Zero-Phasing method
  - RF streak camera
  - T-Cavity
- Electric field of electron techniques
  - SMA monitor
  - Standing wave distribution measurement
  - E/O method



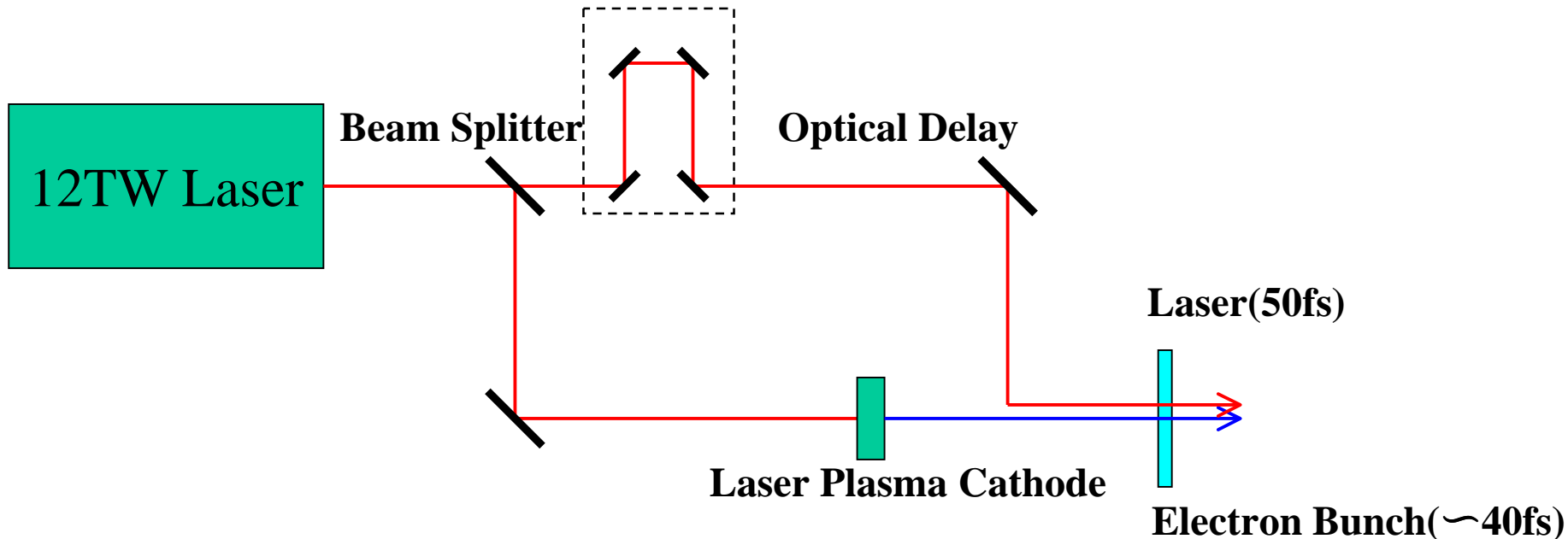
- Radiation techniques
  - Streak camera
  - Interferometer
  - Fluctuation method



Experiment of 10fs electron pulse generation from plasma cathode

# Big Advantage of Laser Plasma Accelerator for Pump-and-probe analysis

- Synchronization is perfectly passive without any electronics.
- No timing jitter and drift between laser and secondary beam.
- Femtosecond time-resolved analysis is surely available after the beam quality and stability are upgraded.





# Summary of Synchronization

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## 1. Laser vs Accelerator Synchronization System via Electronics

Picoseconds time-resolution

## 2. Laser Seeded Staged Accelerator

Femtoseconds time-resolution

Available for multibunches

## 3. Laser Plasma Accelerator

Beam Splitter enables even Attoseconds time-resolution

After Stable and reliable beam generation and diagnosis are established

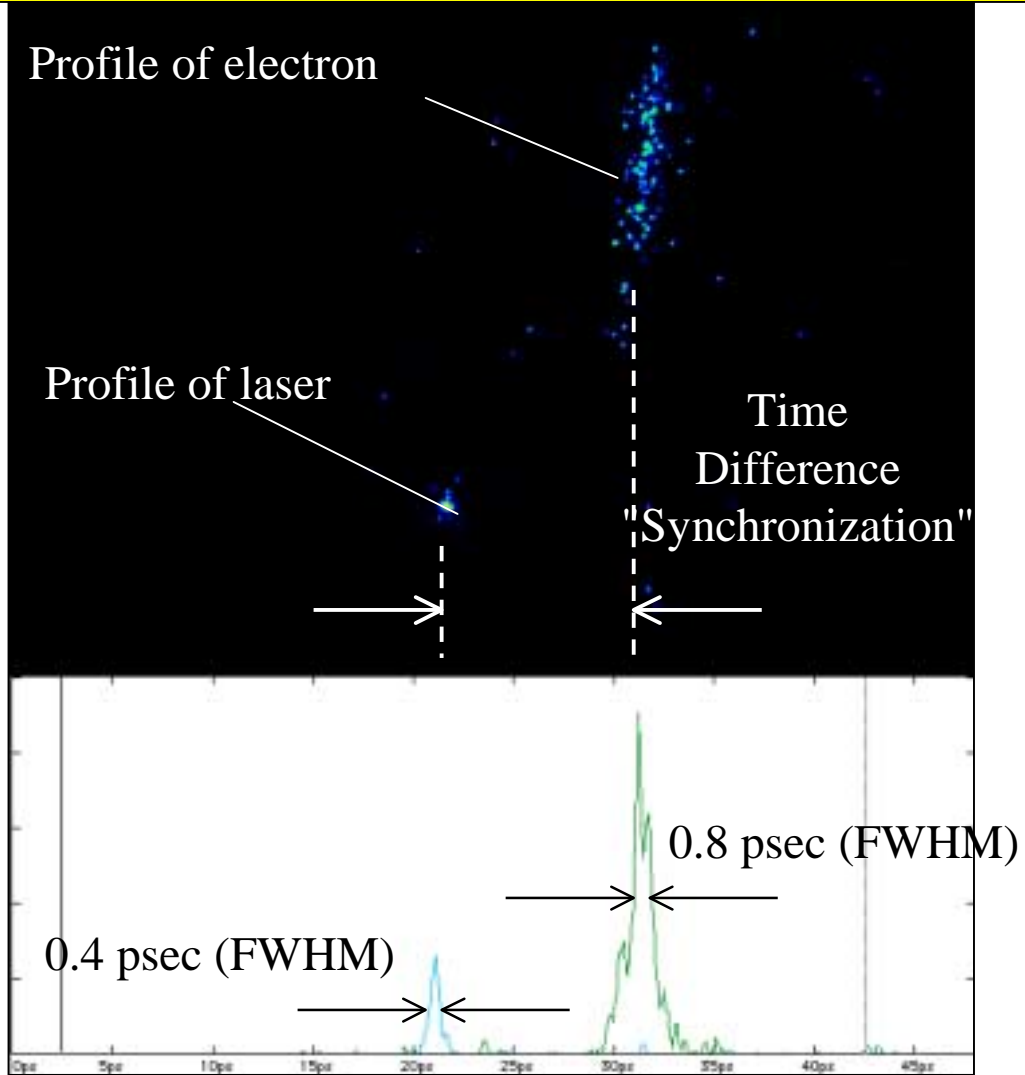
# Synchronization

Femtosecond Streak Camera Image of Synchronization

**Accelerator**

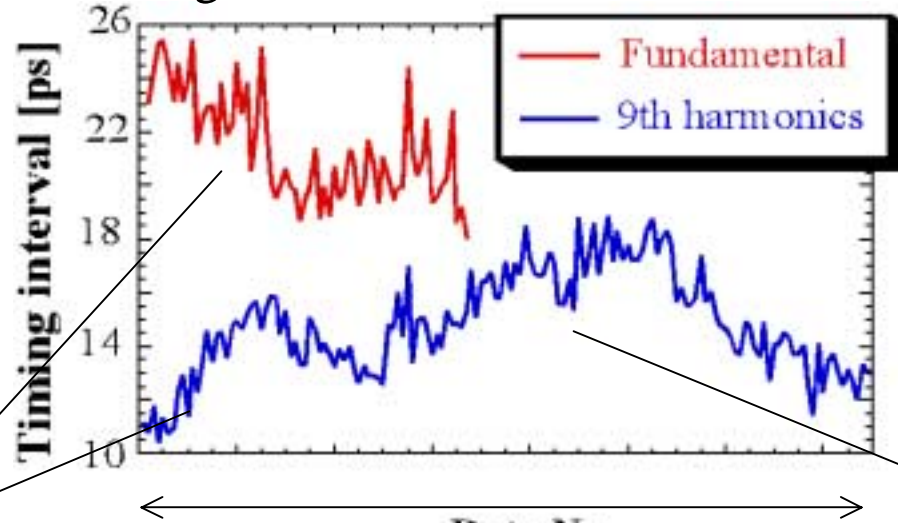
**vs**

**Laser**



# Timing Jitter and Drift

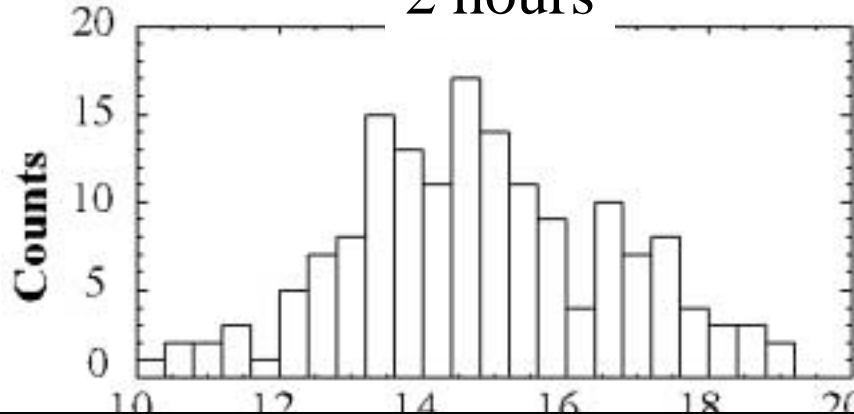
Timing interval between RF and laser



Timing drift of long term was left.

Timing jitter was suppressed.

2 hours



The phase-lock of higher harmonics suppresses the timing jitter, but the timing drift was remained.

# Stable Synchronization

*~ Result of transport line improvement ~*

The pressure effect due to evacuated transport line was suppressed.  
The expansion and contraction effect due to temperature was left.

