MC5

Terahertz frequency-domain spectroscopy referring to as terahertz frequency comb (THz comb spectroscopy)

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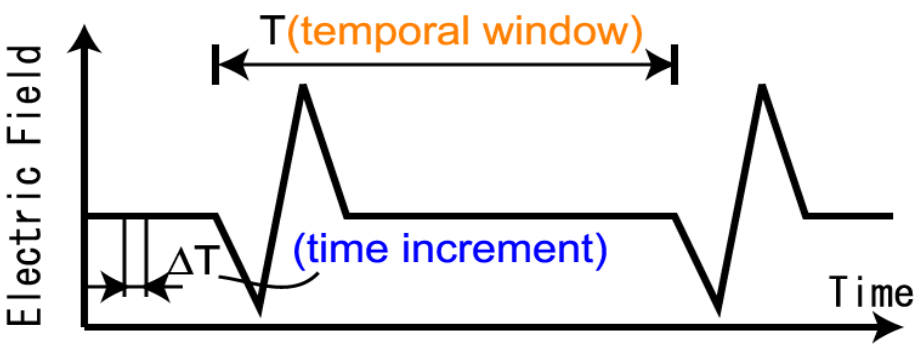
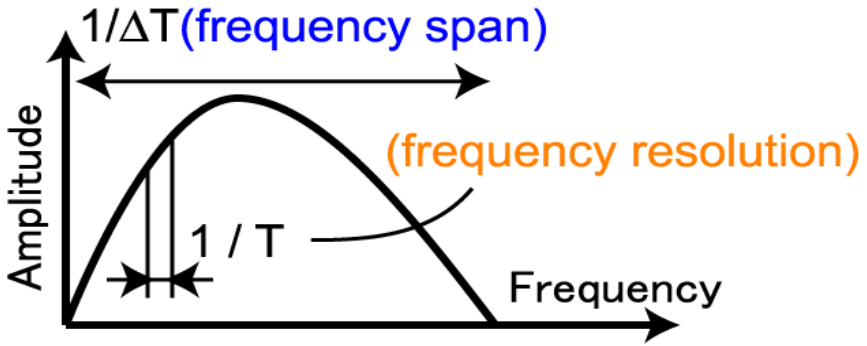
THz time-domain spectroscopy (THz-TDS)



Temporal waveform

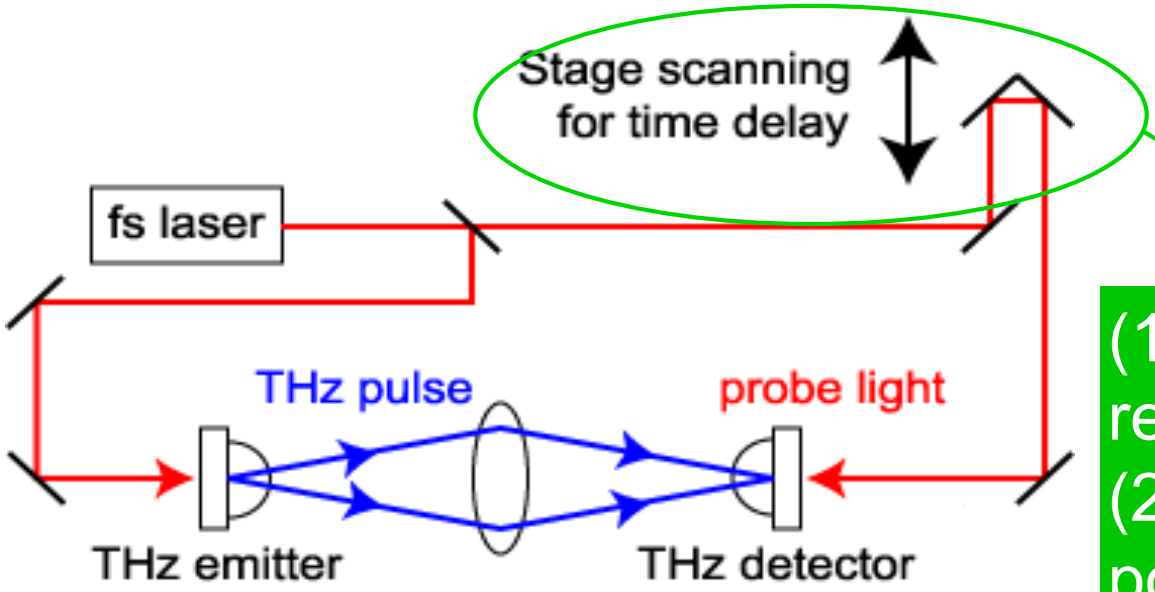
F.T.



Fourier spectrum

Resolution = inverse of temporal window

Accuracy = precision of time delay

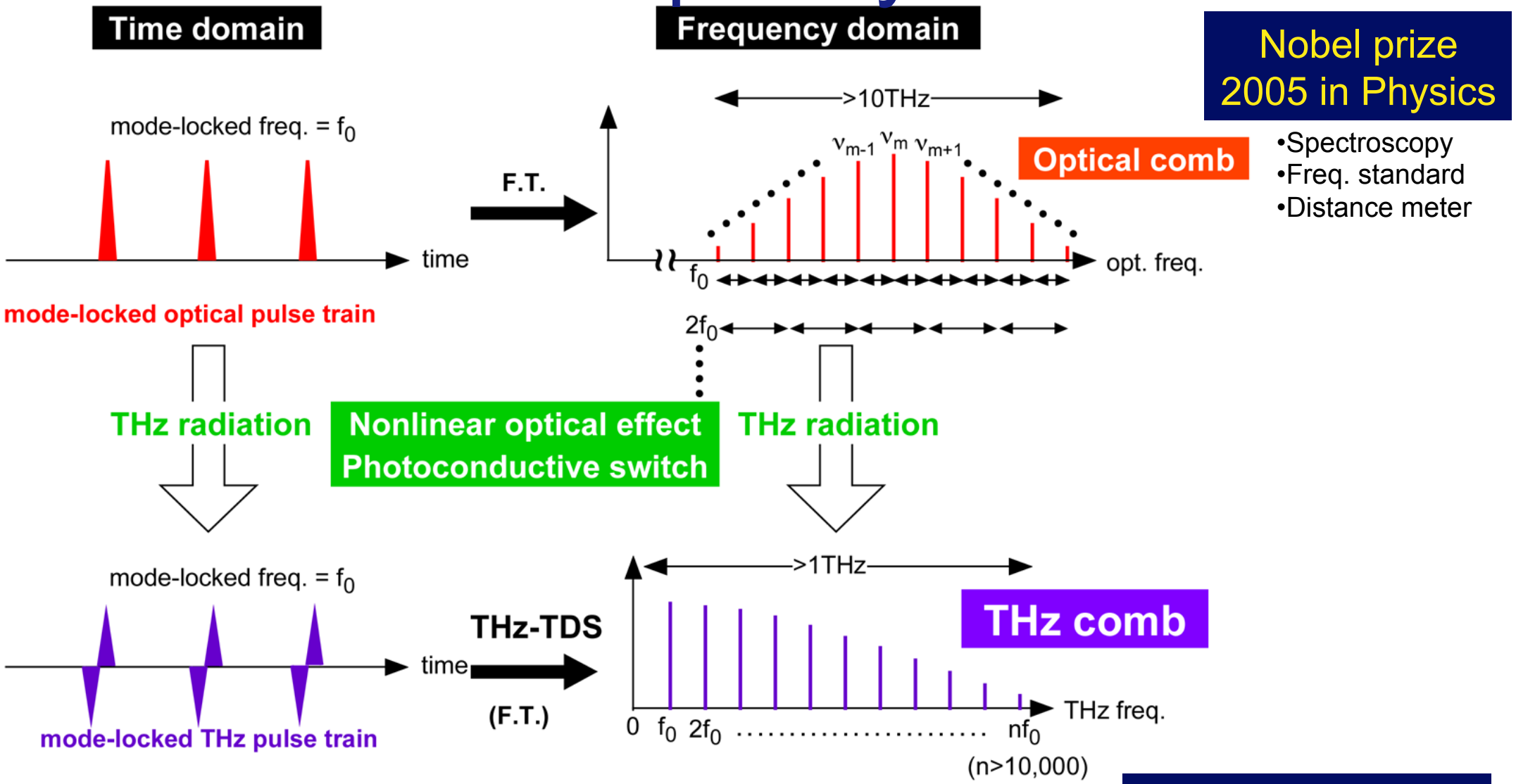


Stage-scanning THz-TDS

Spectral scaling based on moving of mechanical stage

(1) Trade-off between spectral resolution and measurement time
(2) Spectral accuracy depends on positioning precision of stage

THz frequency comb



Nobel prize 2005 in Physics

- Spectroscopy
- Freq. standard
- Distance meter

Attractive features for high-precision THz spectroscopy

Accurate, stable, broadband selectivity, high spectral purity, exact multiplication, and absolute frequency calibration

Frequency ruler in THz region!

Present talk

THz frequency comb for high-precision THz spectroscopy

(1) Generation of accurate THz comb

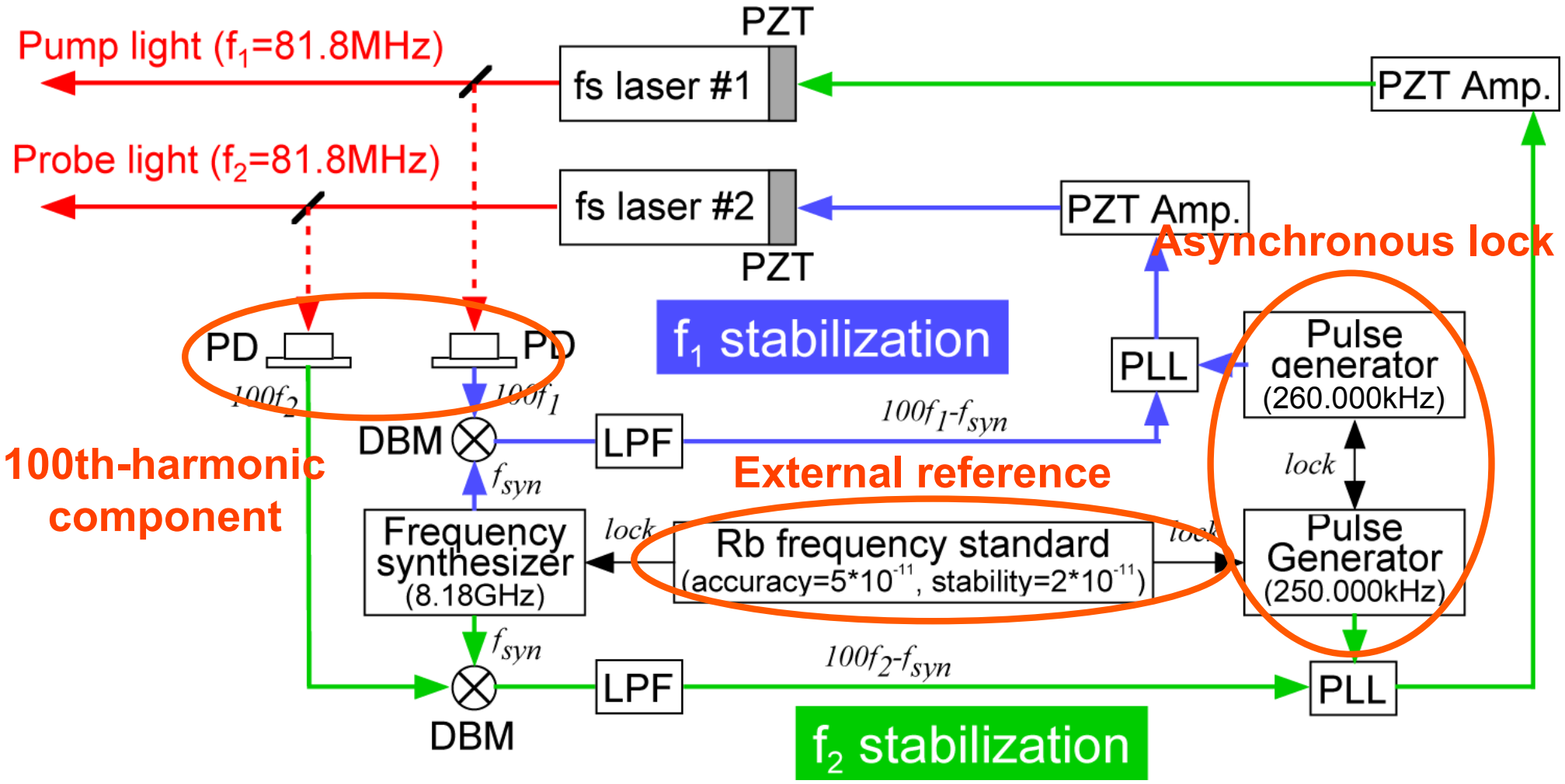
Use of ML-frequency-stabilized femtosecond laser and photoconductive antenna for THz generation

(2) Accurate reading of frequency scale of THz comb

Multi-frequency-heterodyning photoconductive detection

Ref. T.Yasui et al. “Terahertz frequency comb by multifrequency-heterodyning photoconductive detection for high-accuracy, high-resolution terahertz spectroscopy” APL **88**, 241104 (2006)

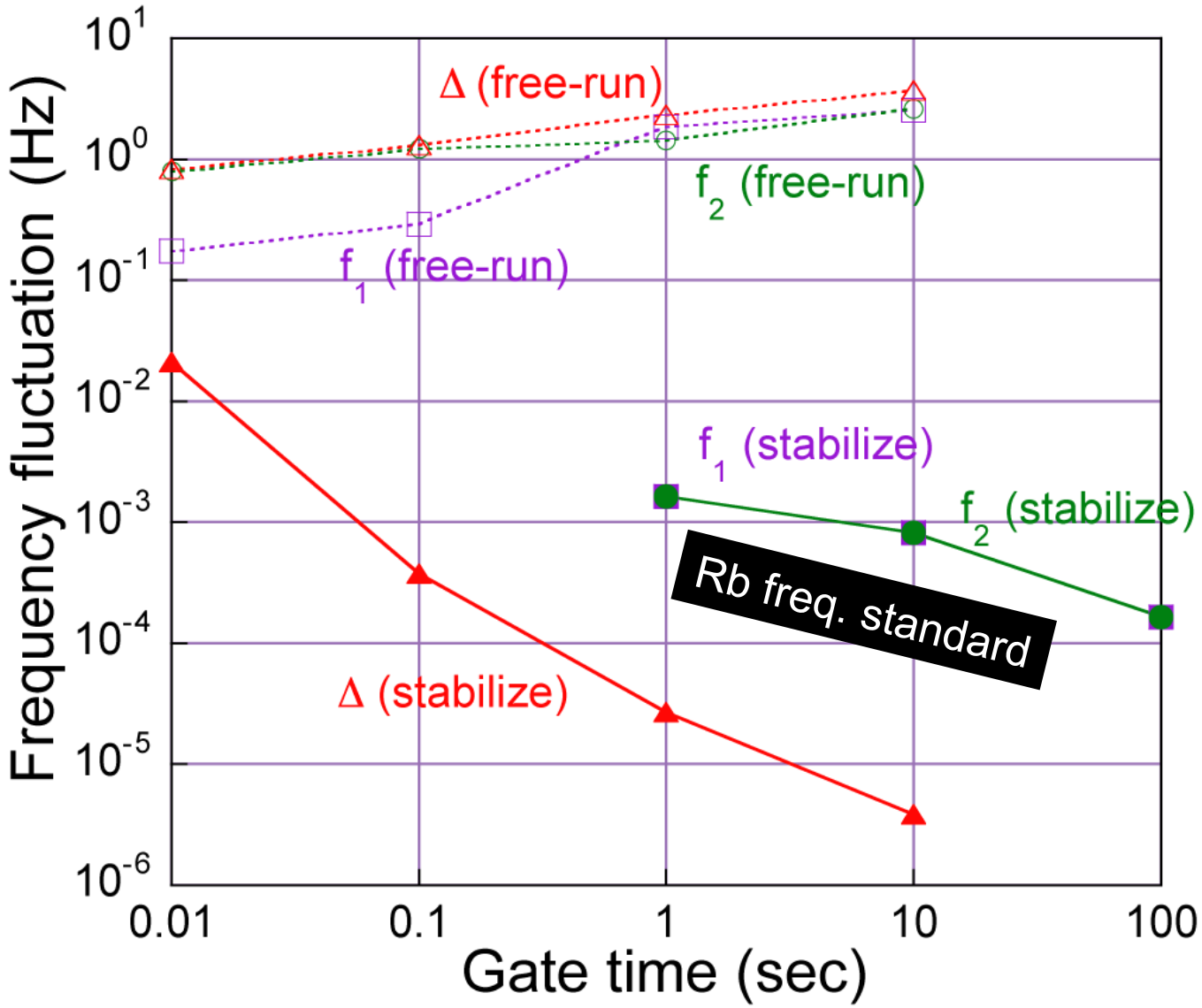
Laser source for THz comb spectroscopy



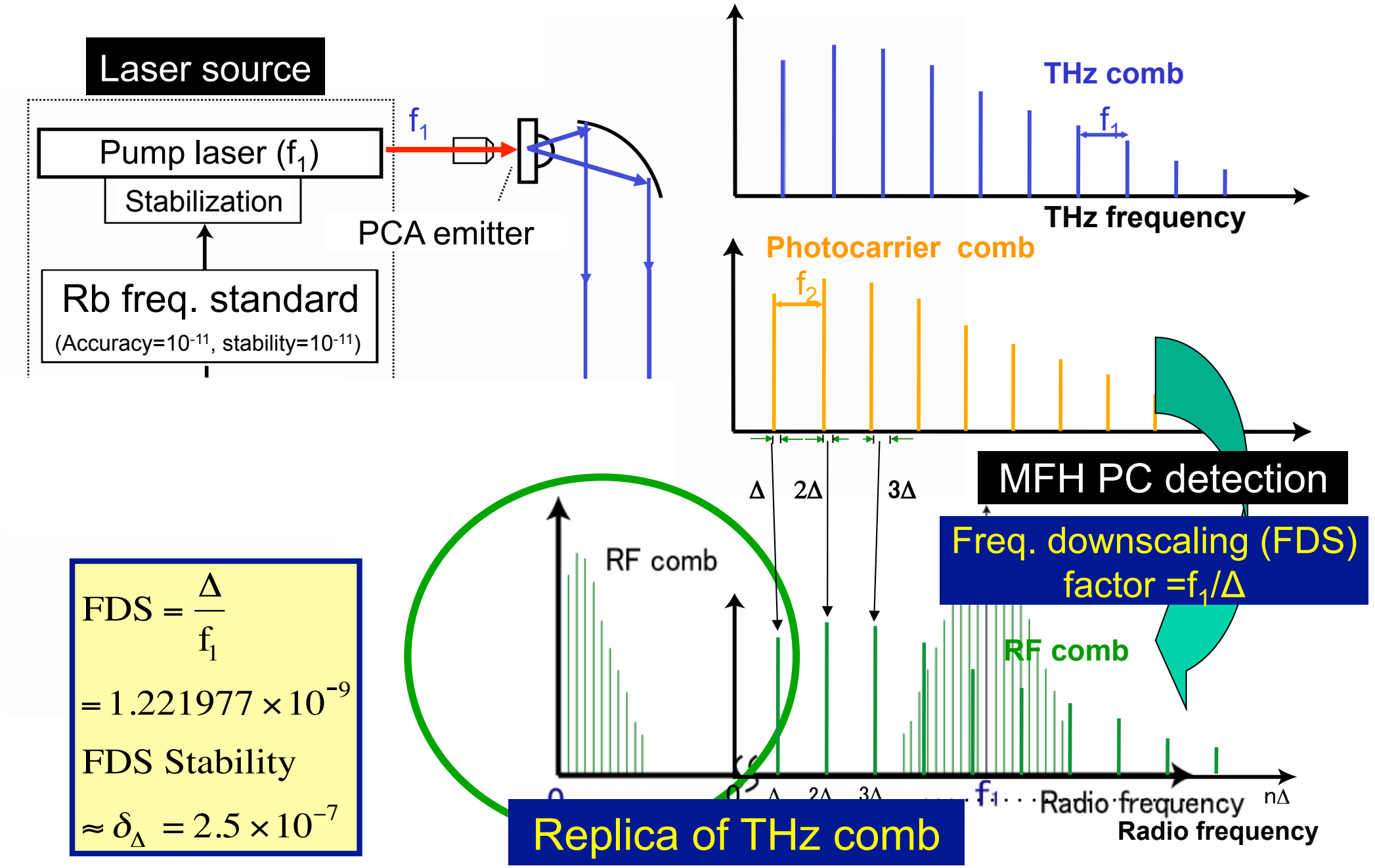
f_1=81,834,630,000Hz, f_2=81,834,630,100Hz

$\Delta = f_1 - f_2 = 100$Hz

Frequency stability of laser source



Multi-frequency-heterodyning photoconductive detection



$$\mathrm{FDS} = \frac{\Delta}{f_1}$$

$$= 1.221977 \times 10^{-9}$$

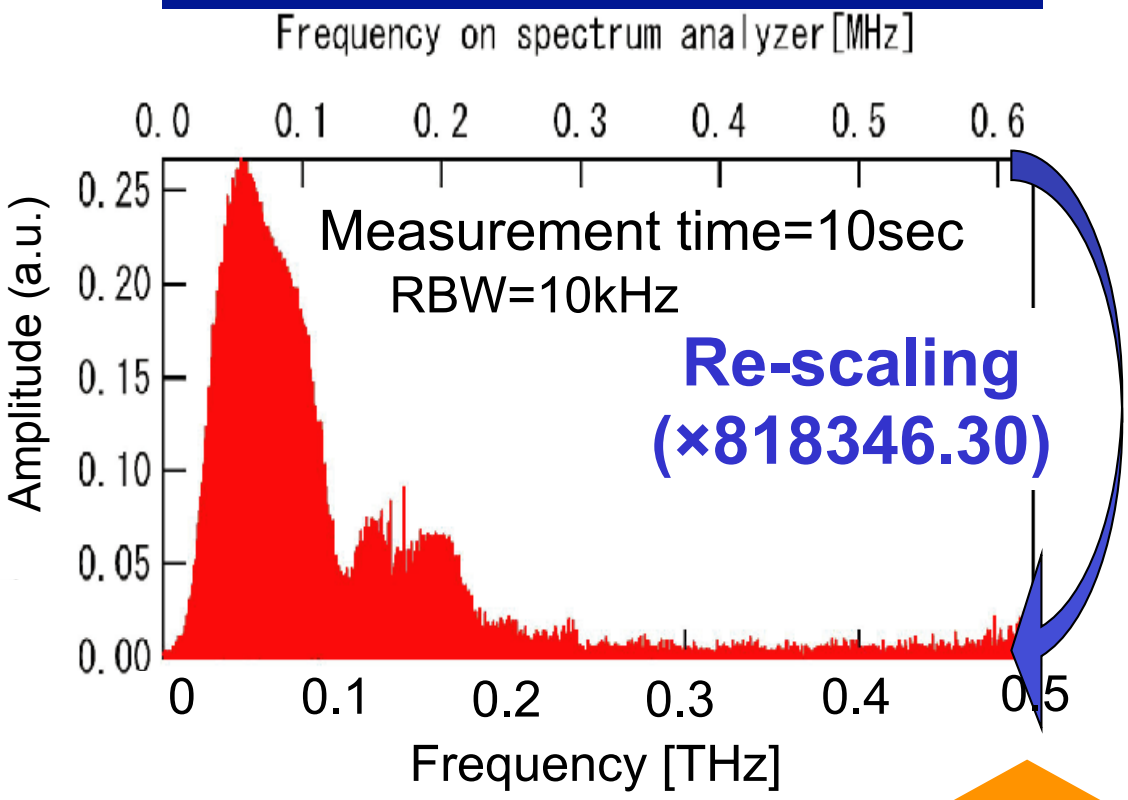
FDS Stability

$$\approx \delta_\Delta = 2.5 \times 10^{-7}$$

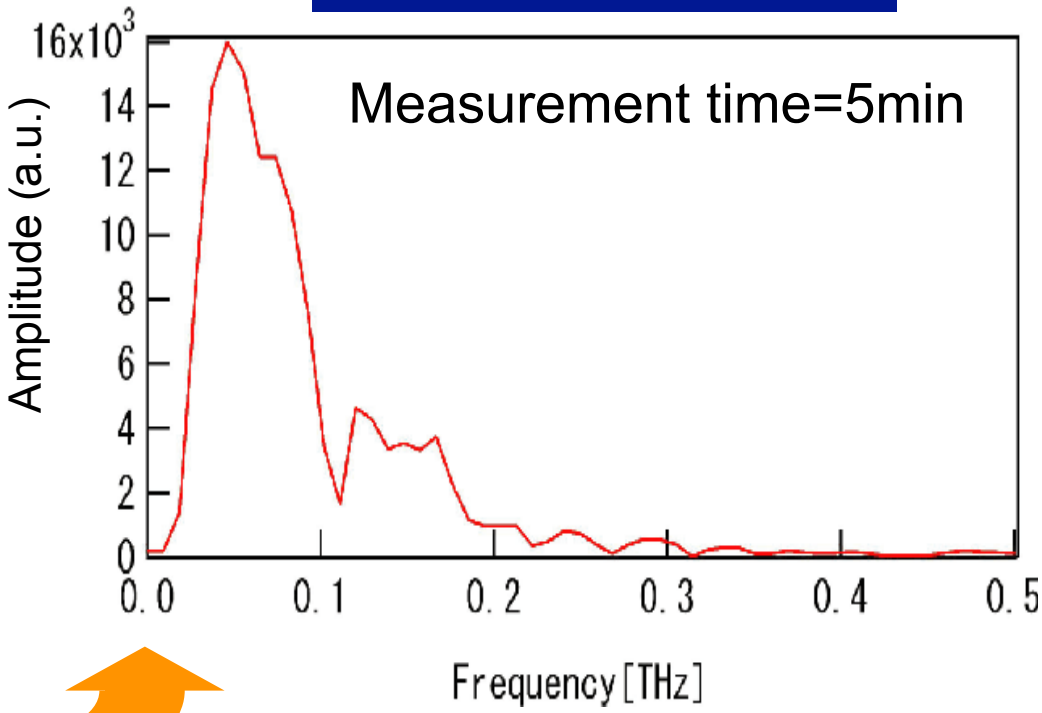
Comparison of amplitude spectrum

（Bowtie-PCA emitter and Bowtie-PCA detector）

THz comb spectroscopy

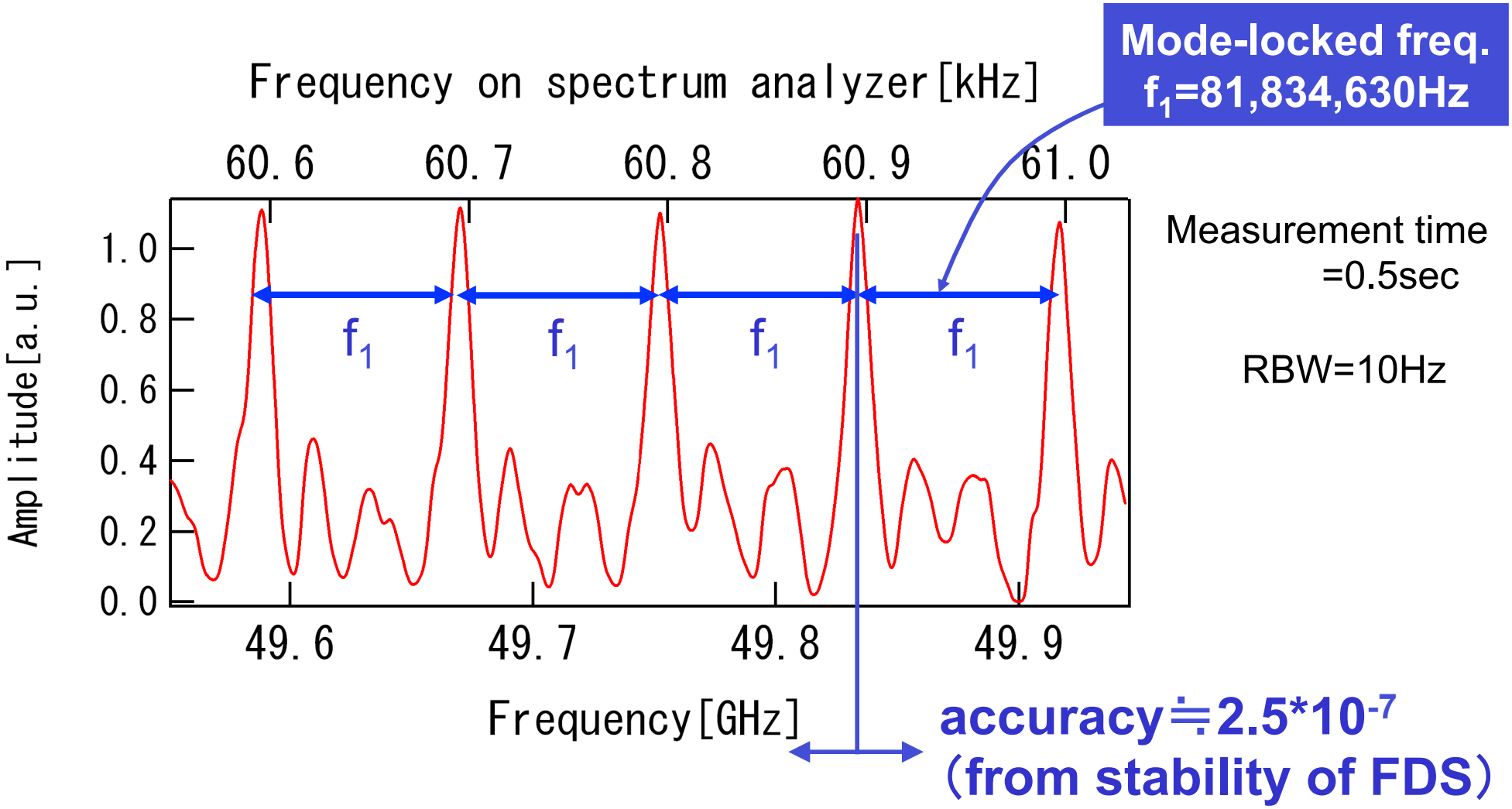


Stage-scanning THz-TDS



THz amplitude spectrum is measured correctly !

Direct observation of THz comb mode

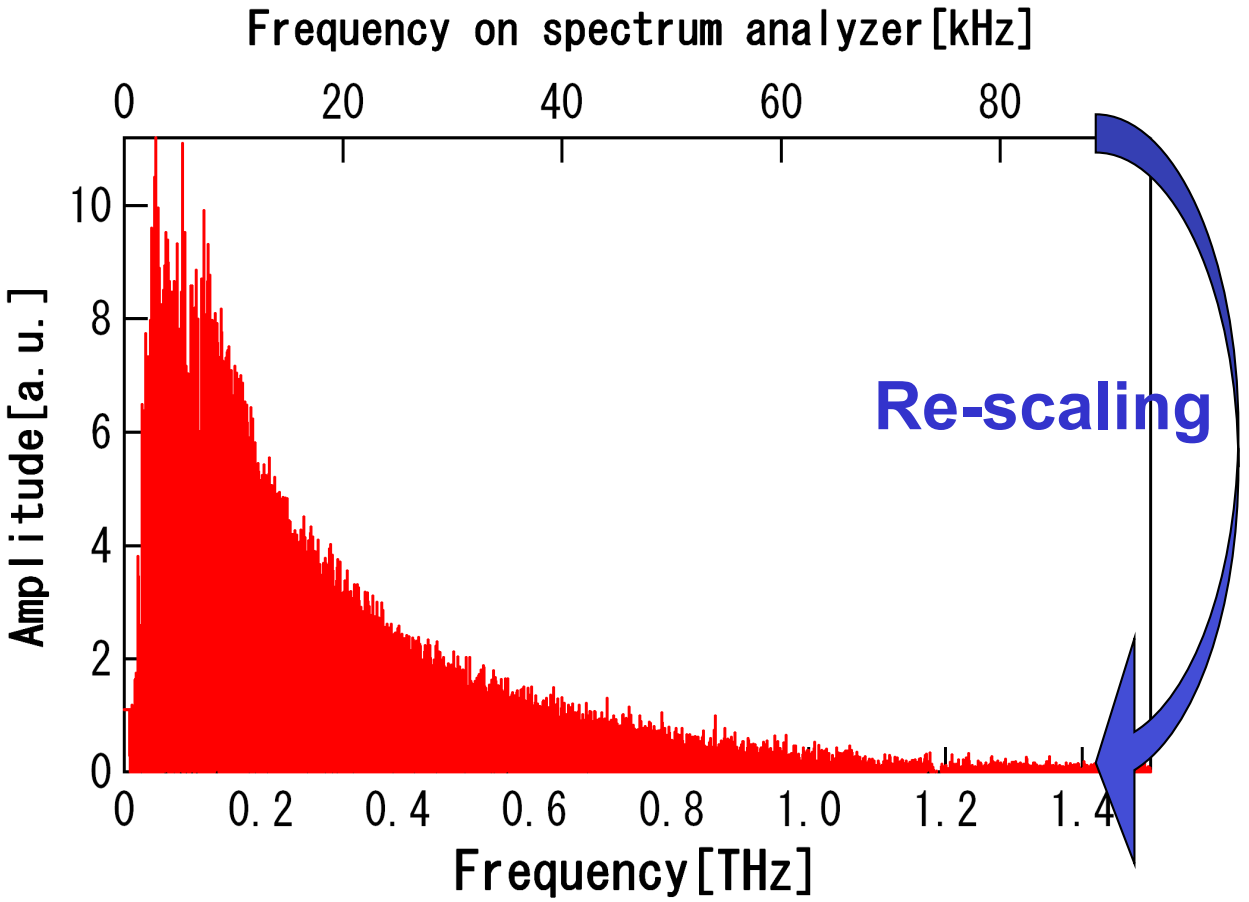


THz frequency scale with **accuracy of $2.5*10^{-7}$** and **resolution of 81.8MHz**

Expansion of spectral range

Modifications

(1) THz detector
⇒dipole PCA
(2) FDS factor
⇒16,366,926,000@Δ=5Hz
(3) Current preamplifier
⇒×5*10$^{7V/A}$@100kHzBW



Spectral range is over 1THz !

Summary

Comparison with conventional THz-TDS

	THz comb spectroscopy	**Conventional THz-TDS**
Time delay	Unnecessary	Mechanical stage
FFT	Unnecessary	Computer
Measurement time	10sec	5min
Spectral resolution	81.8MHz	9GHz
Spectral accuracy	$2.5*10^{-7}$ (depend on FDS stability)	10^{-2} (depend on positioning precision of stage)
Amplitude spectrum	Possible	Possible
Phase spectrum	Impossible	Possible