

# **THz Comb Spectroscopy**

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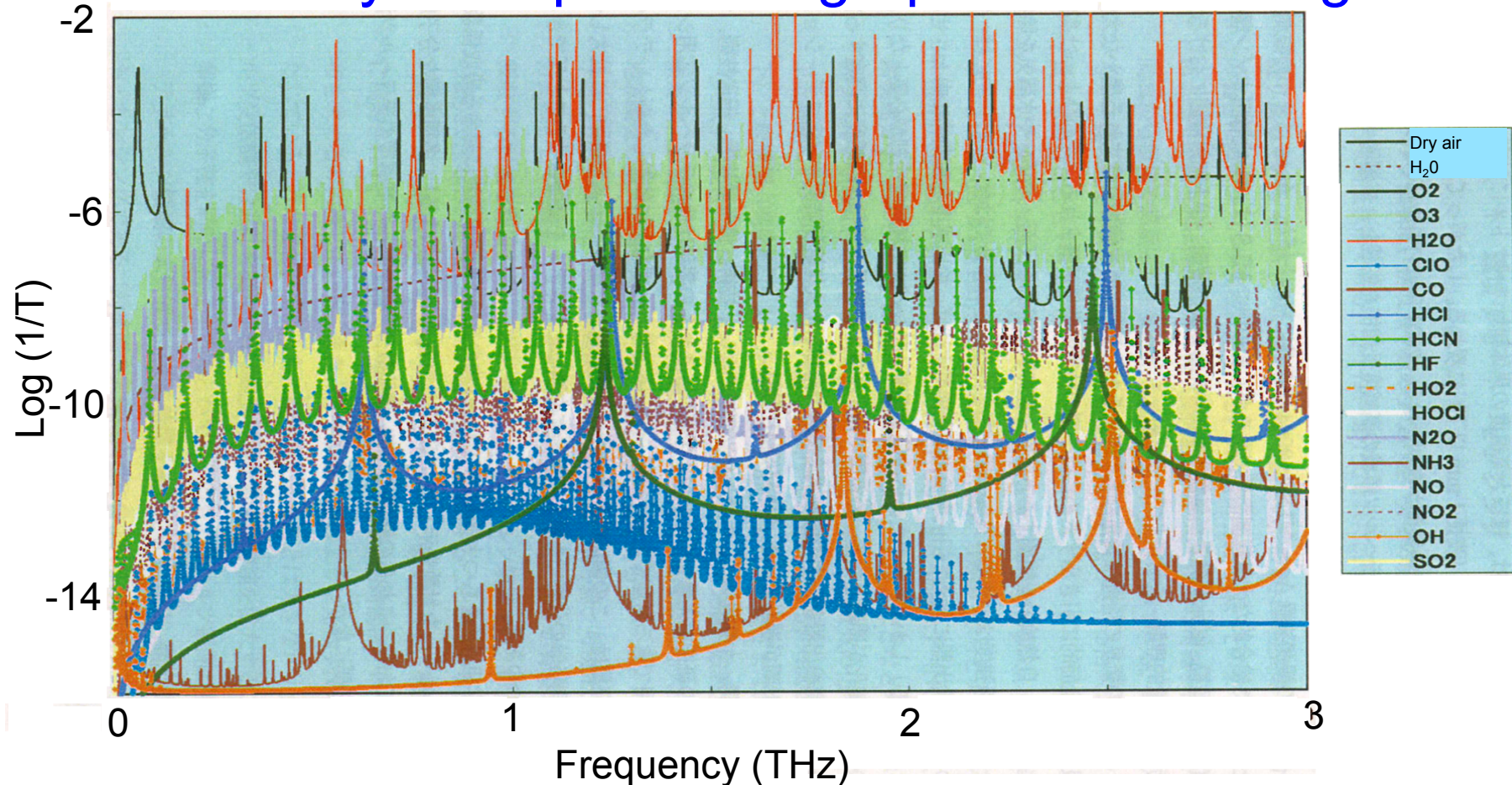
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**LTST-ISUPTW 2012@Wuhan**

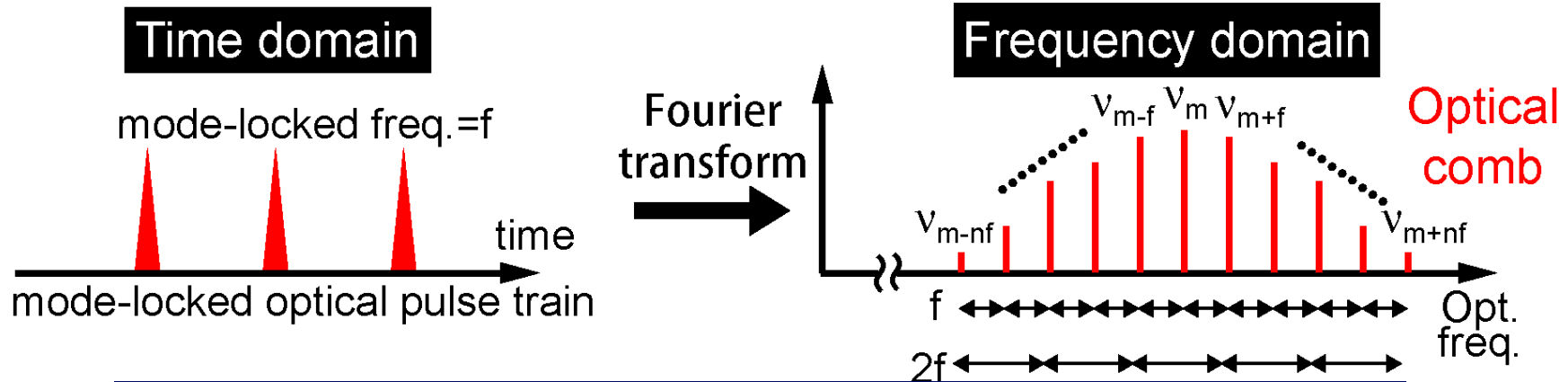
# Analysis of atmospheric gas molecules

Particularly rich spectral fingerprints in THz region

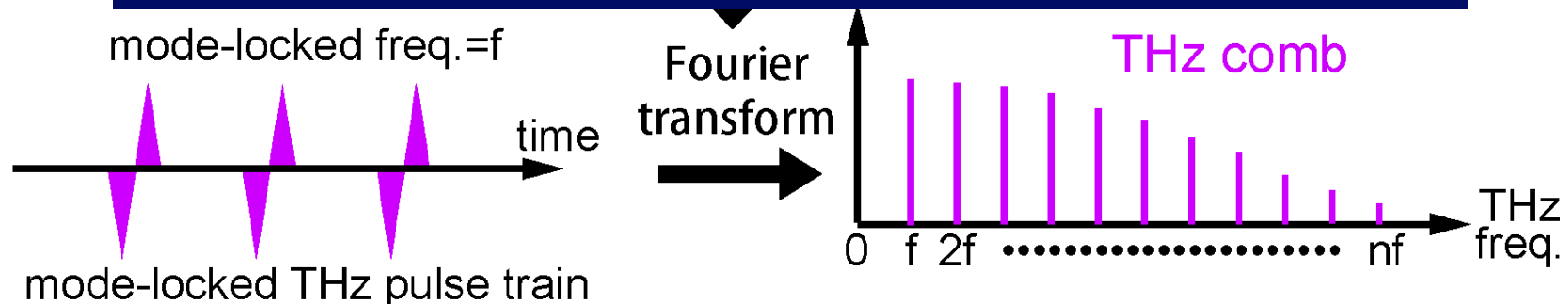


*To measure densely distributed spectral fingerprints correctly, high accuracy, high resolution, and broadband are required.*

# Optical comb and THz comb



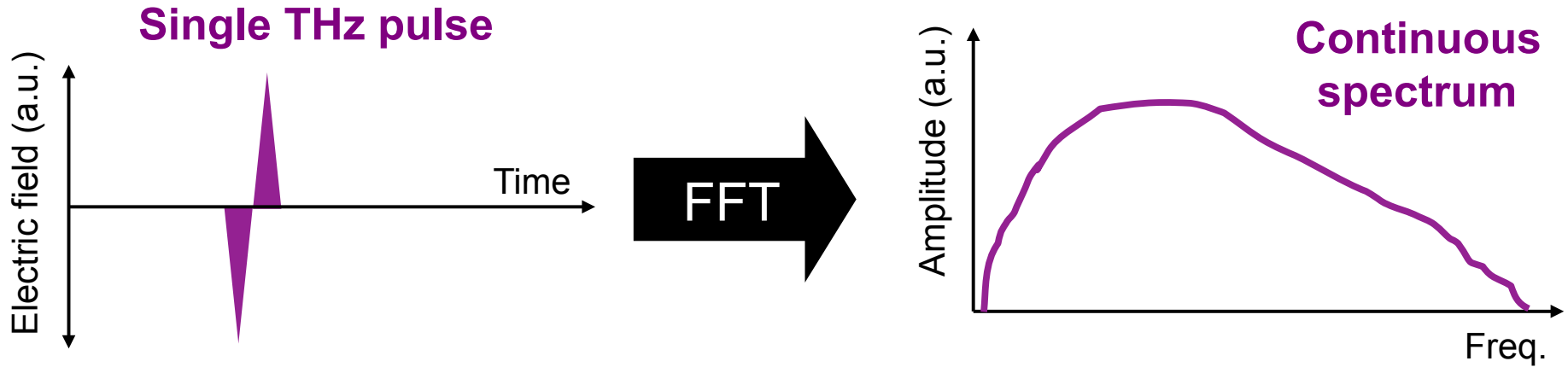
*Precise frequency marker  
for broadband THz spectrum*



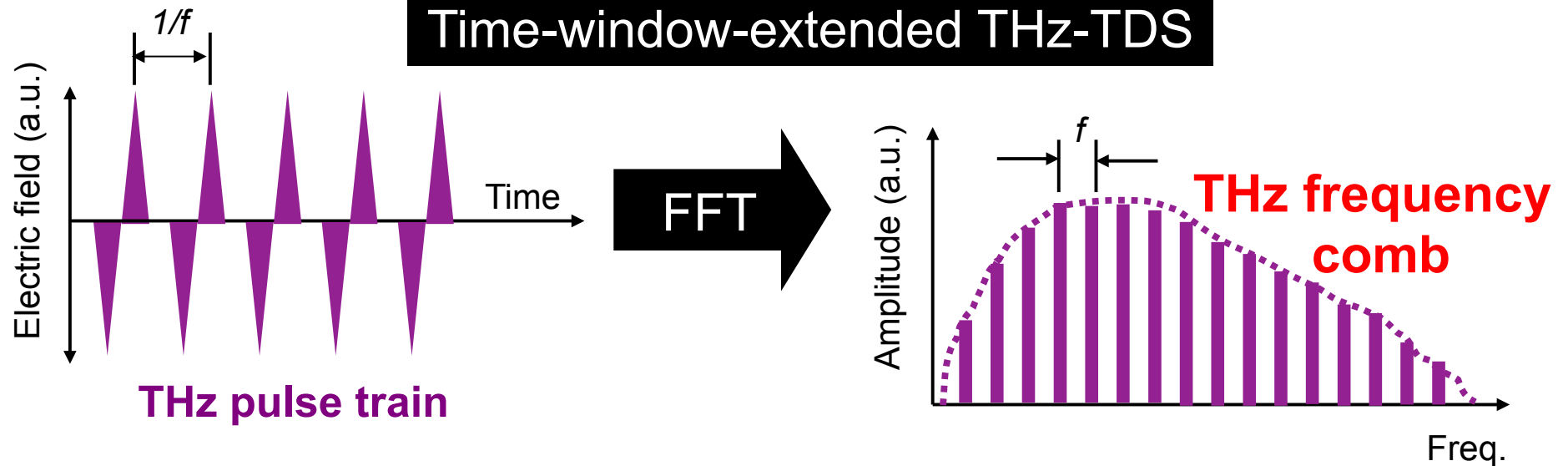
Simple, broadband selectivity, high spectral purity,  
and absolute frequency calibration

# How to measure THz comb

## Traditional THz-TDS with mechanical time-delay scanning

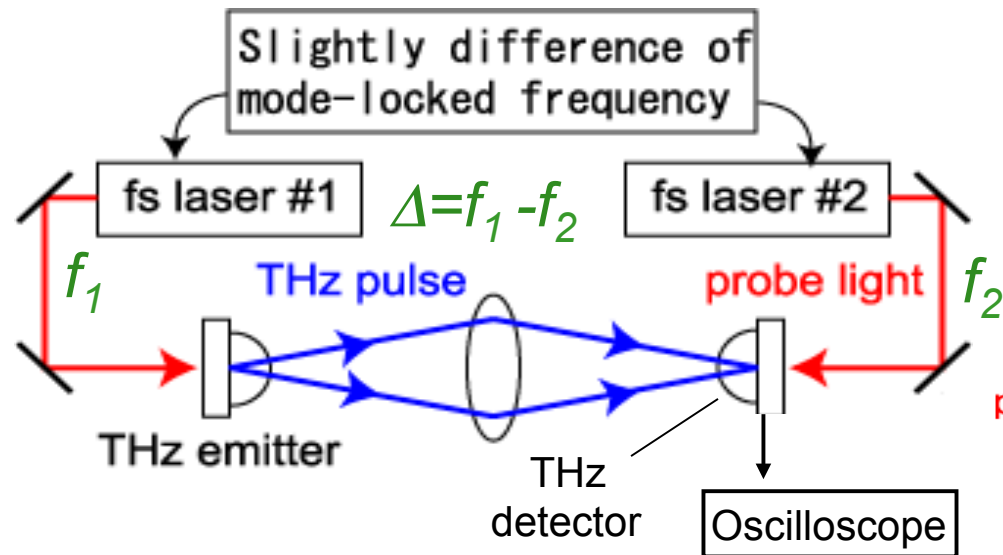


## Time-window-extended THz-TDS

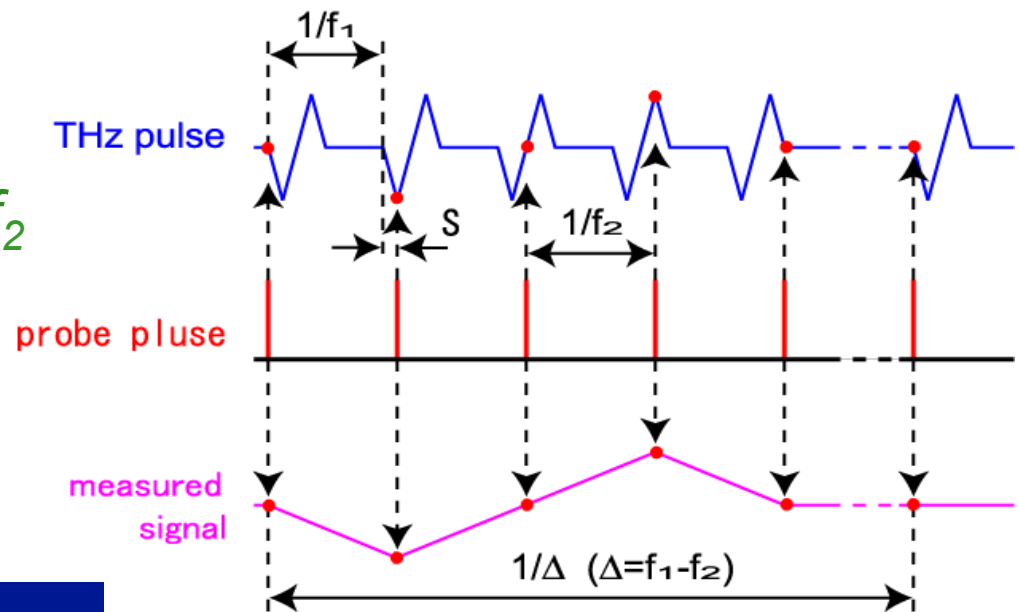


# Asynchronous-optical-sampling THz-TDS (ASOPS-THz-TDS)

ref) T. Yasui, *Appl. Phys. Lett.* 87, 061101 (2005).



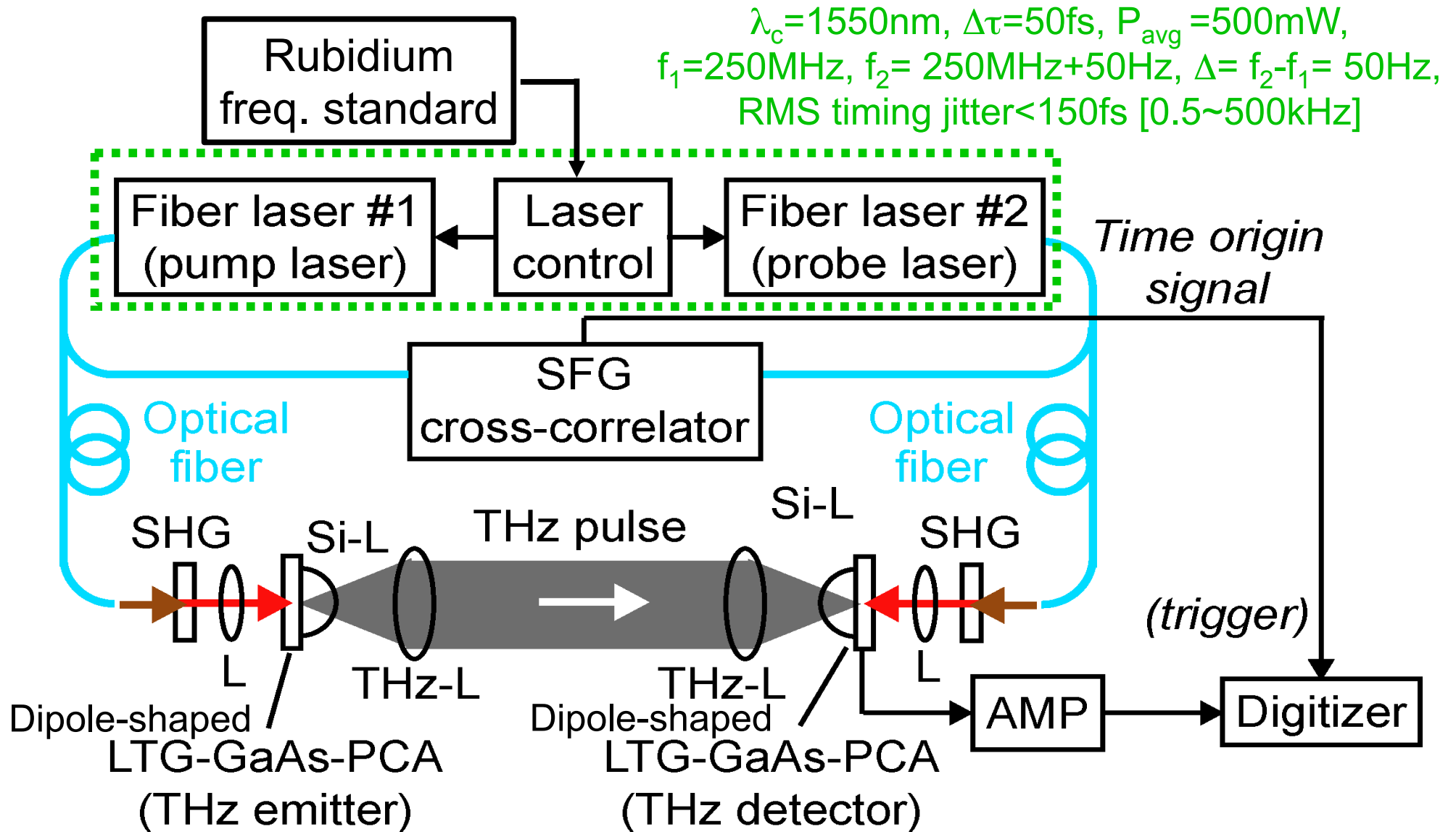
Overlap timing between THz and probe pulse is automatically shifted every pulse



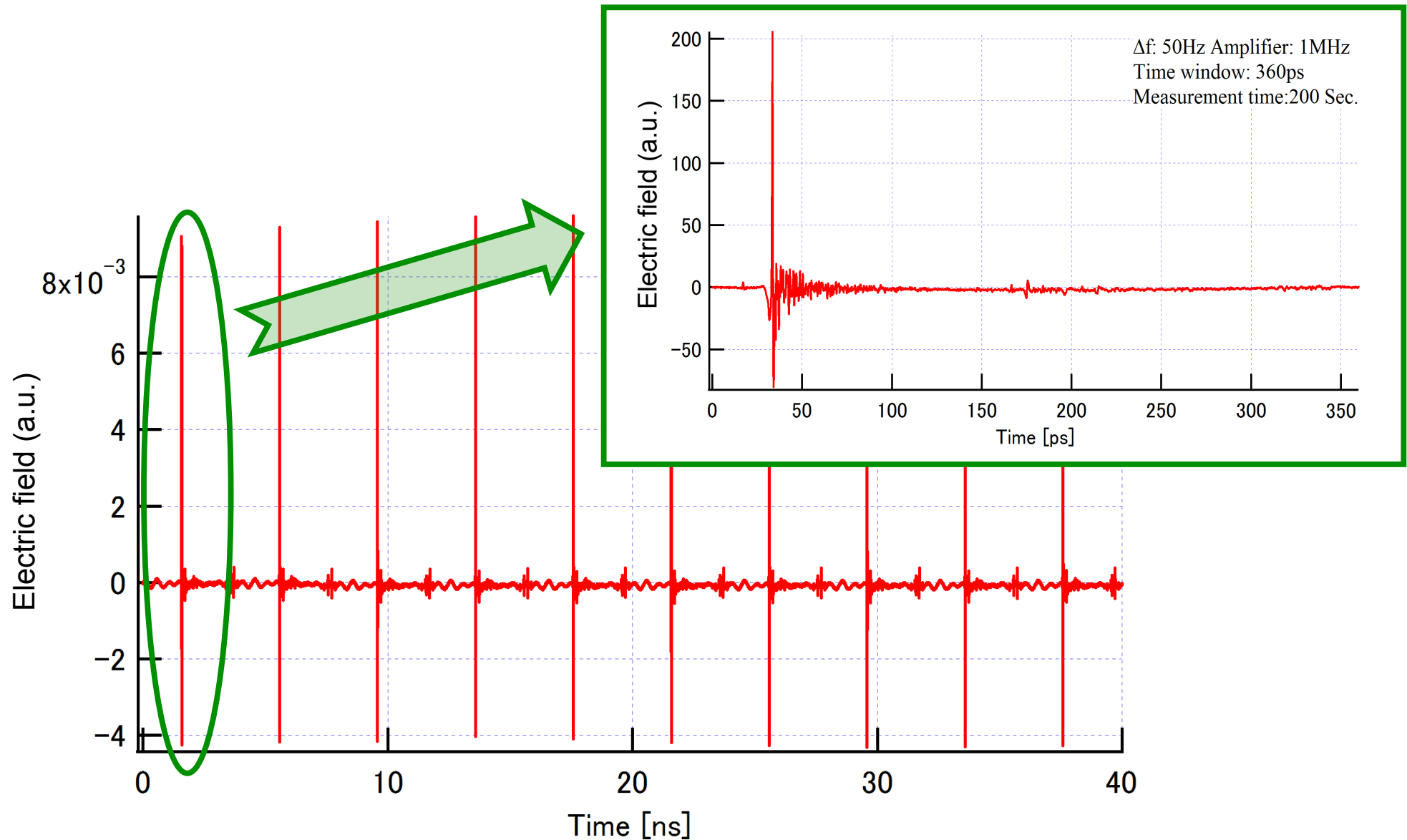
- No need for mechanical time-delay scanning
- No limitation for size of time window

Time scale of ps THz pulse is linearly expanded to  $\mu\text{s}$  order

# Experimental setup



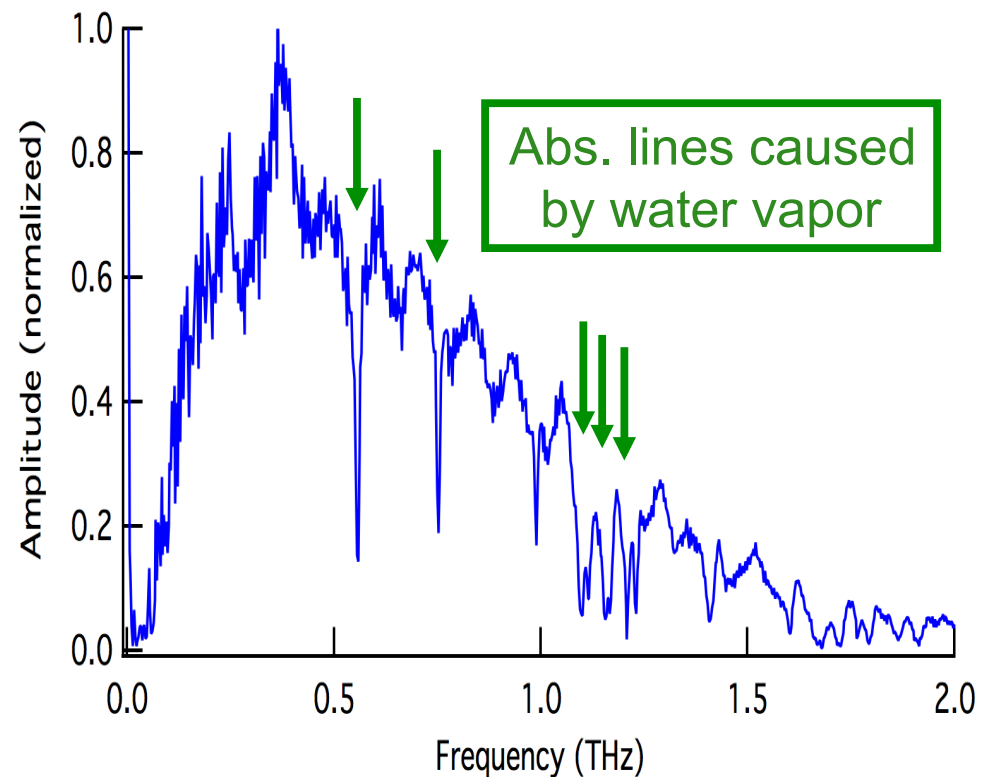
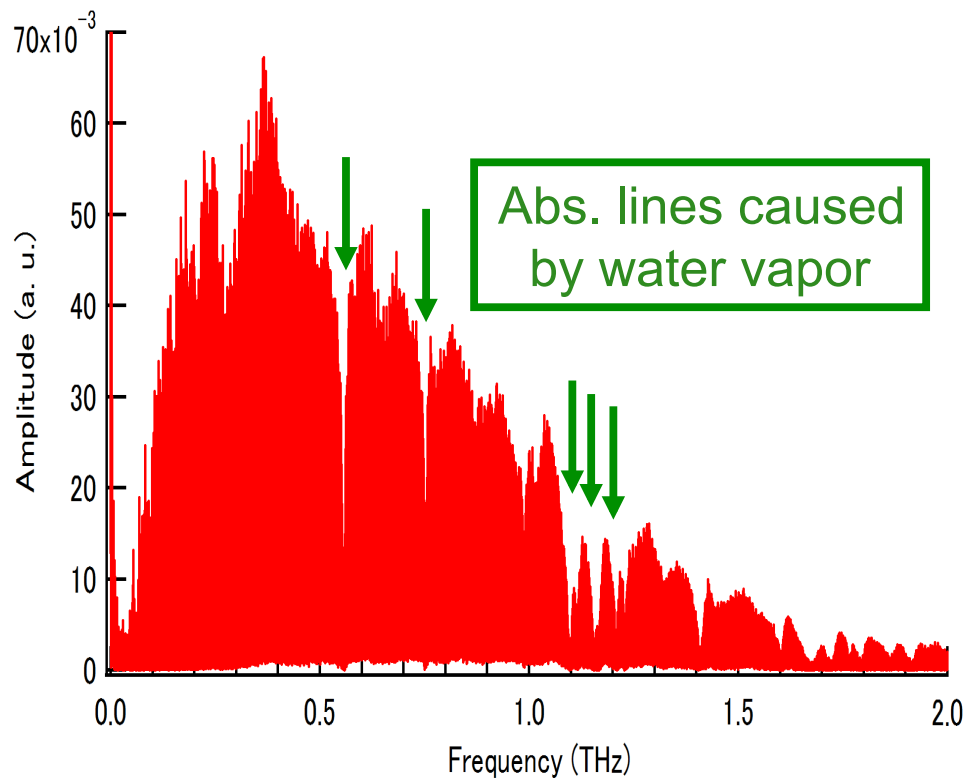
# Temporal waveform of 10 consecutive THz pulses



# Amplitude spectrum of THz comb

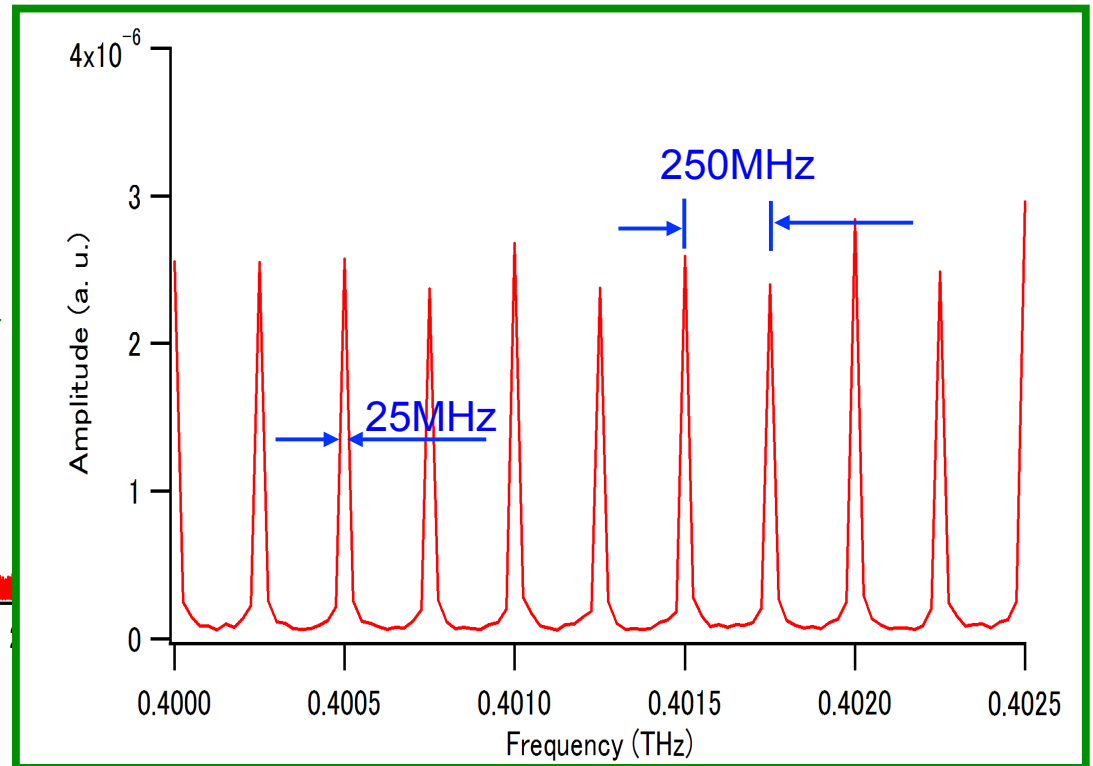
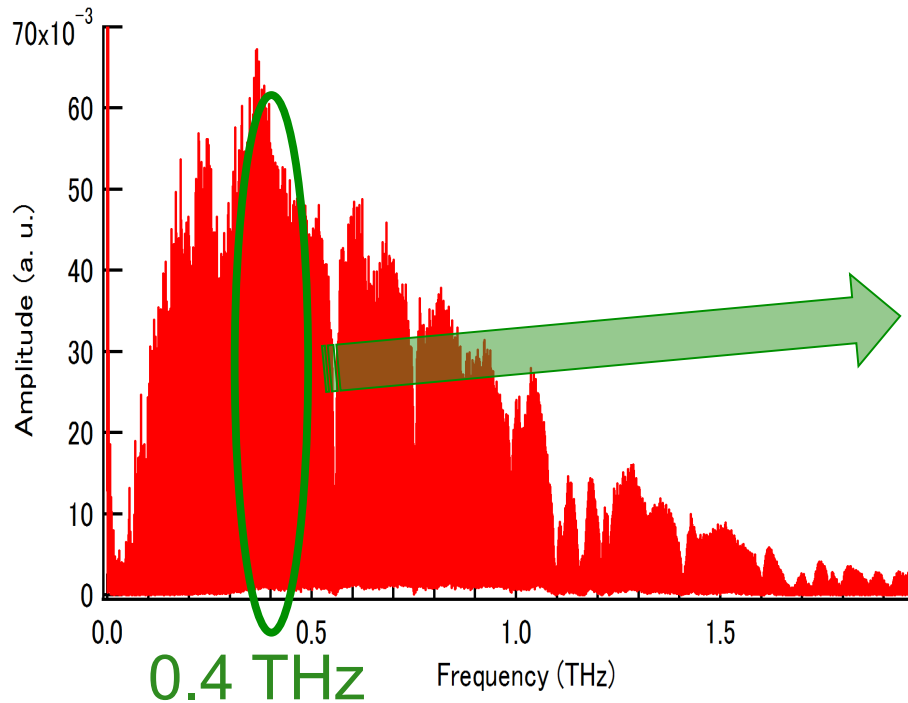
- 10 consecutive pulses (time window=40ns)

- Single THz pulses (time window=0.36 ns)





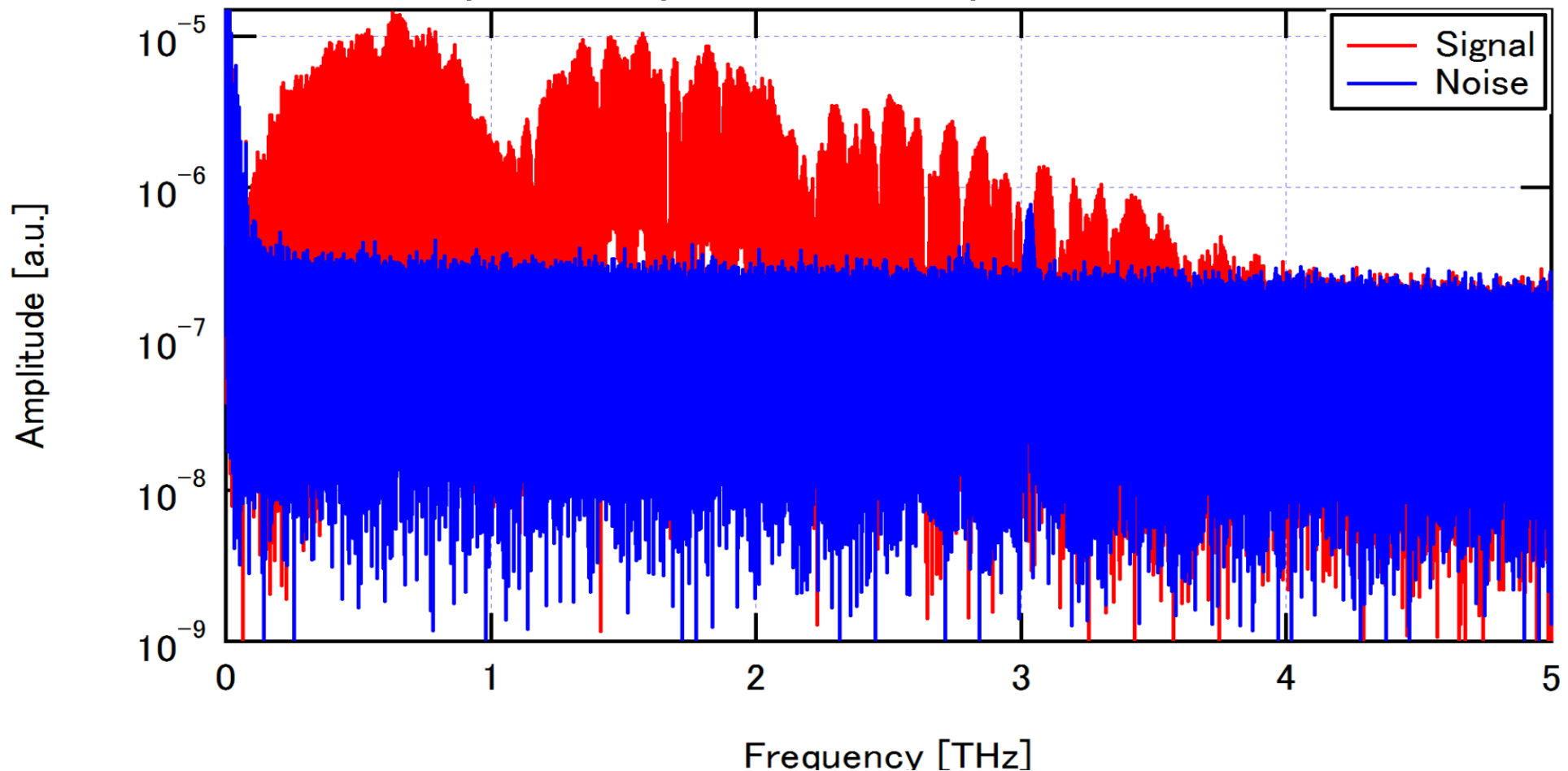
# Detailed spectrum of THz comb mode



Frequency spacing = 250MHz = mode-locked frequency  
Mode linewidth = 25 MHz = inverse of time window

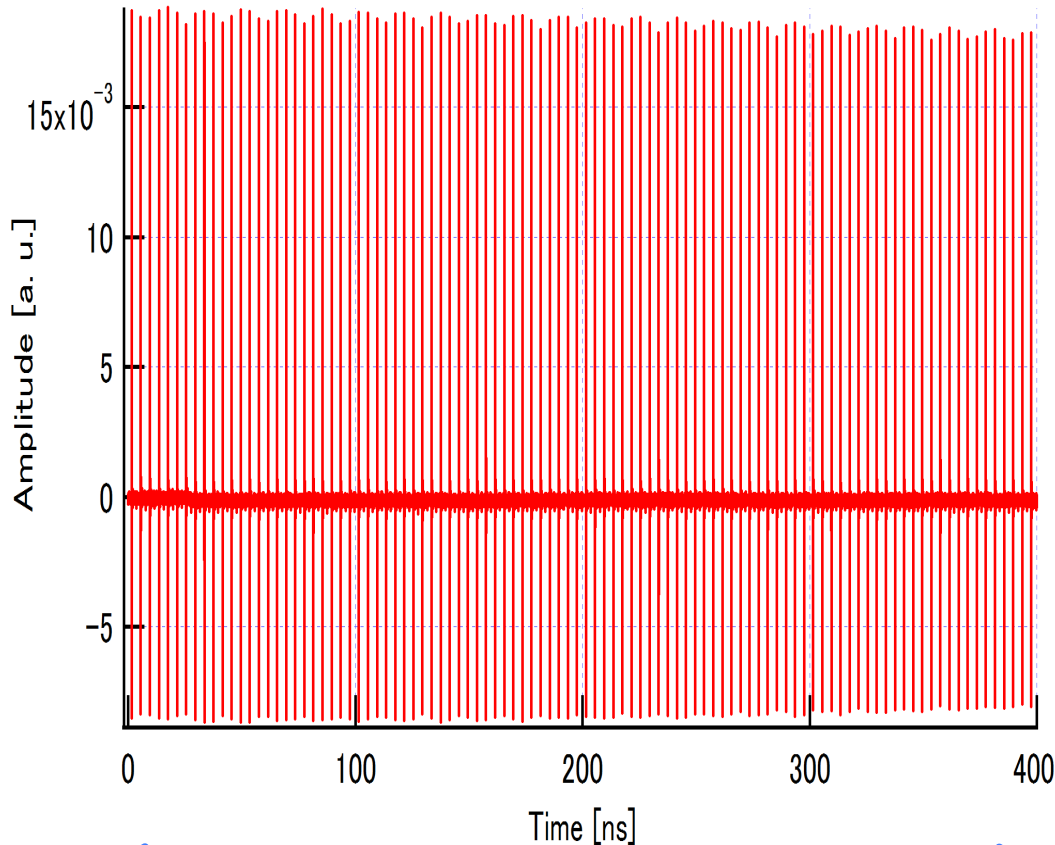
# Broadband spectrum using DAST crystal as THz emitter

THz detector: Dipole-shaped LT-GaAs photoconductive antenna

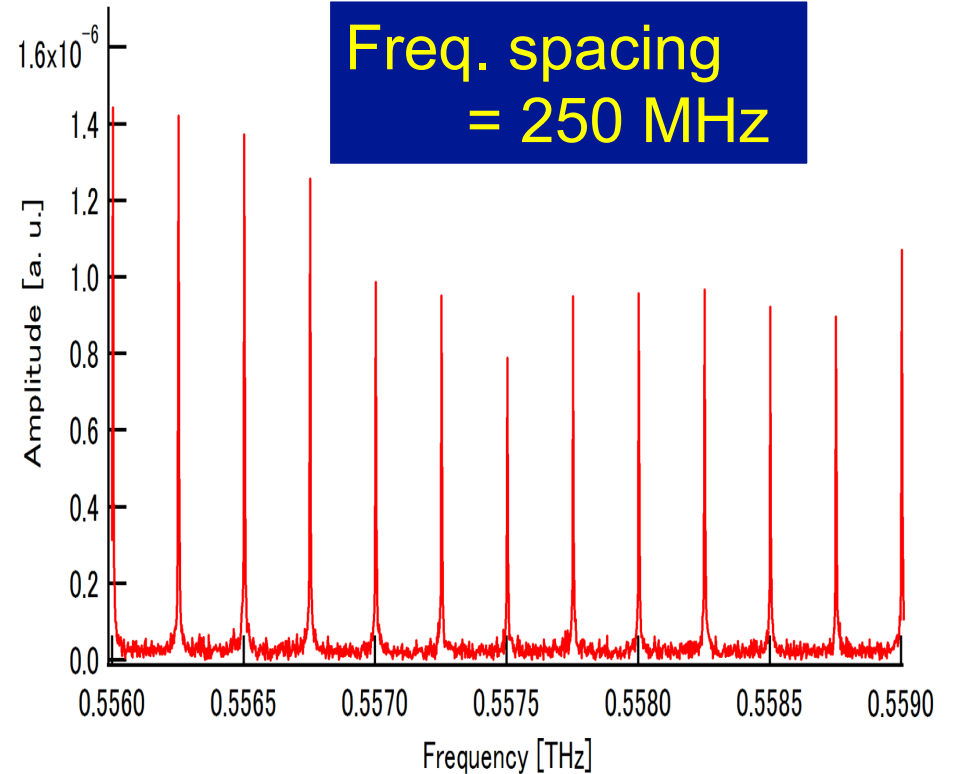


# Extend time window up to 100 pulse periods

## Temporal waveform

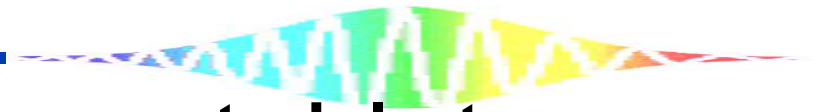


## Amplitude spectrum



← Corresponding to mechanical time-delay scanning by 60 meter →

Linewidth = 2.5MHz

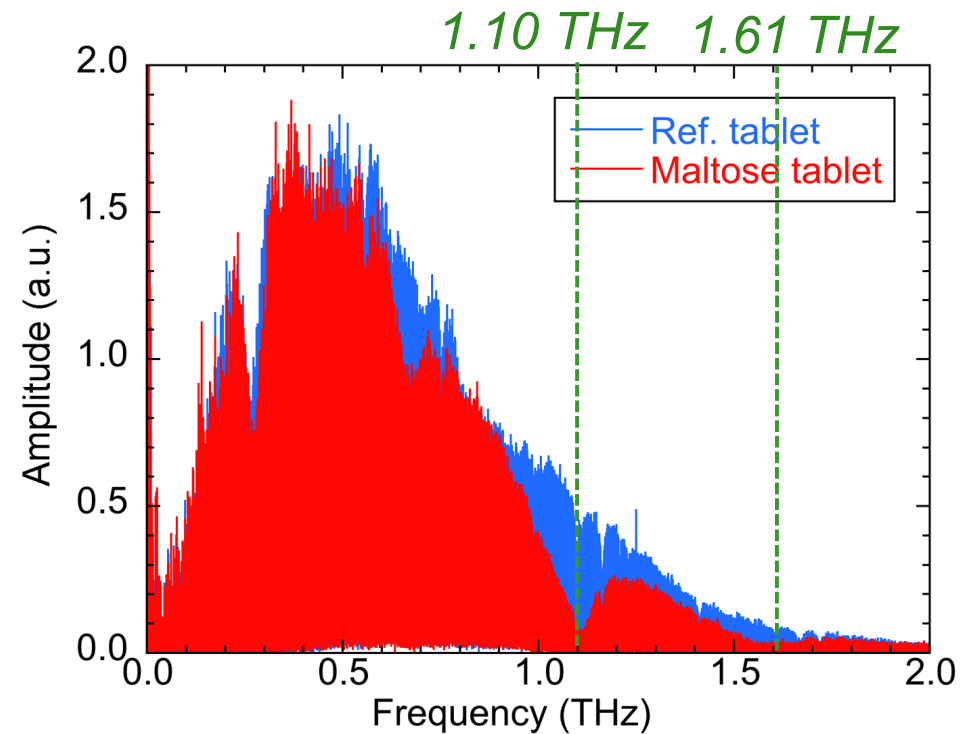
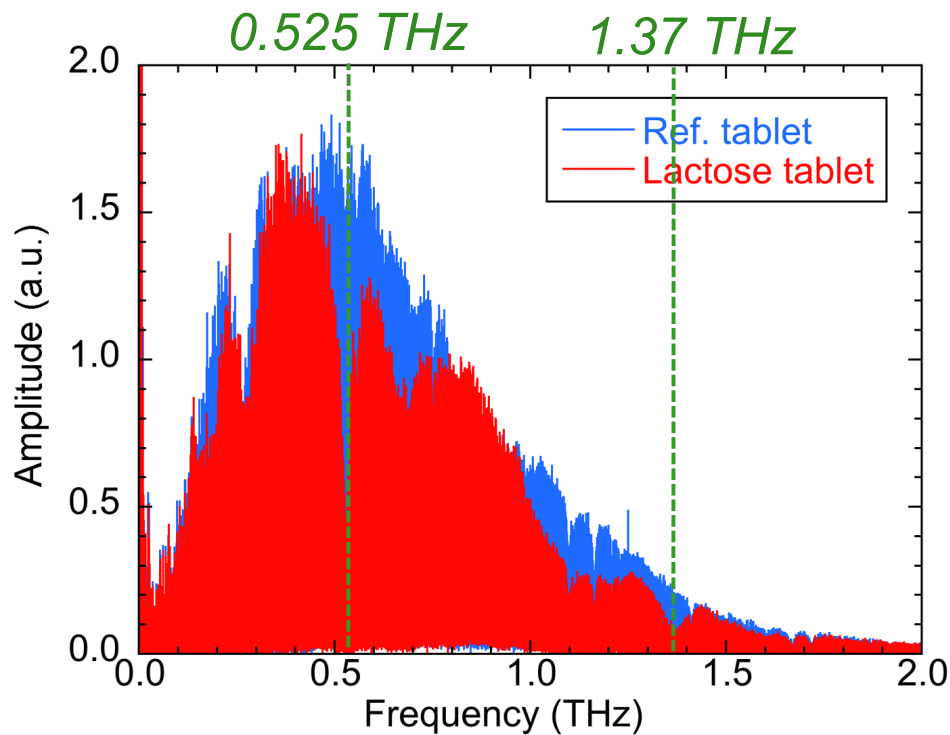


# Spectroscopy of sugar tablets

Lactose

D-maltose

THz spectral fingerprints



# Spectroscopy of low-pressure water vapor

Rotational transition  $1_{10} \leftarrow 1_{01}$ : 0.5569360THz@NASA database

H<sub>2</sub>O@1500Pa with N<sub>2</sub>@17kPa  
(Pressure broadening=1.5GHz)

H<sub>2</sub>O@600Pa with N<sub>2</sub>@1400Pa  
(Pressure broadening=250MHz)

NASA database

