

The logo for SPEL (Spectra Quest Lab, Inc.) is located in the top-left corner. It consists of the letters 'S', 'P', 'E', and 'L' in a stylized, bold font, arranged in a triangular pattern. The 'S' and 'L' are on the left side, and the 'P' and 'E' are on the right side, with the 'P' and 'E' being slightly higher than the 'S' and 'L'.

# Coherent THz light source based on photo-mixing with a UTC-PD and ASE-free tunable diode lasers

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Spectra Quest Lab. Inc



# UTC-PD is ...

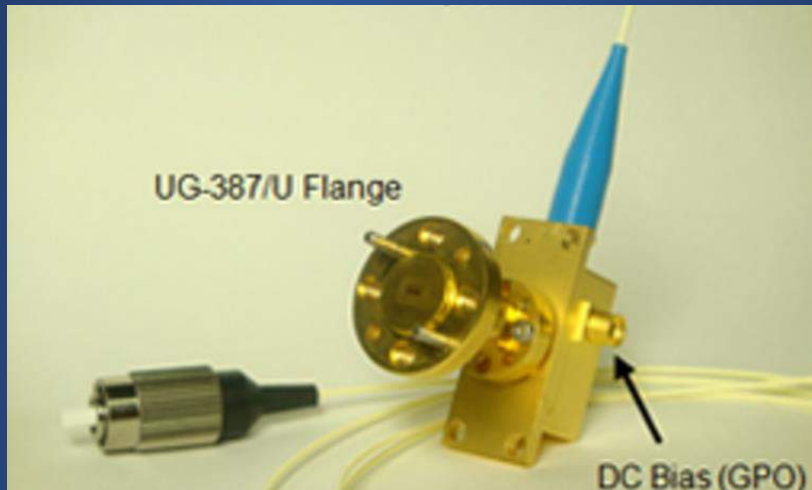
High-Speed Photodiode

UTC-PD : Uni-Traveling-Carrier Photodiode

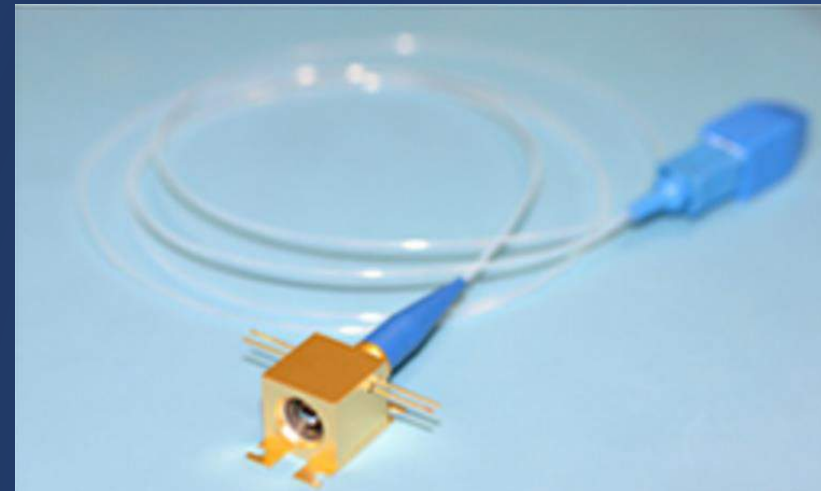
➔ THz-Wave Photomixer Module

Produced by NTT-EL

Waveguide-Output Type



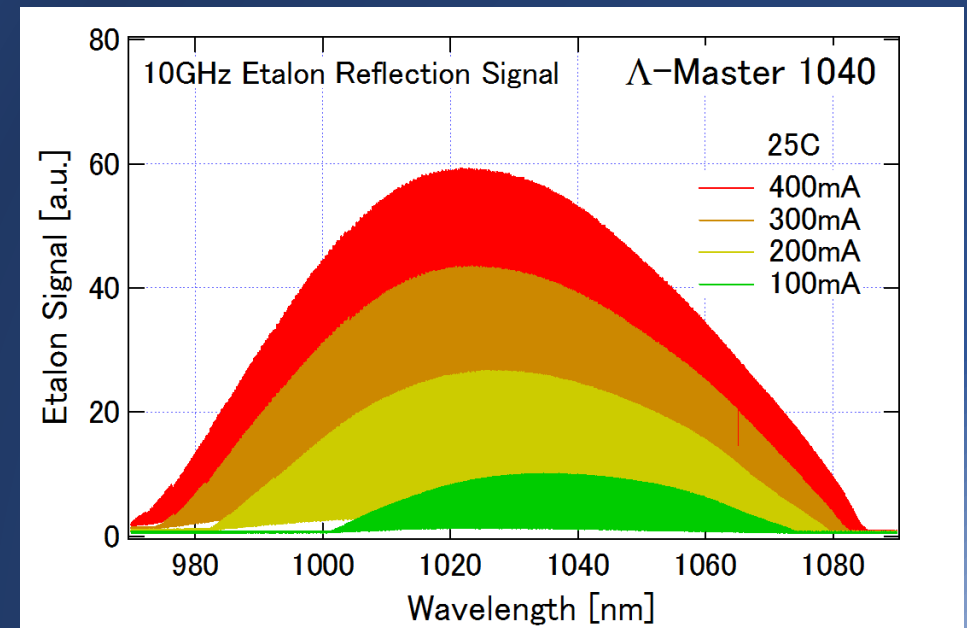
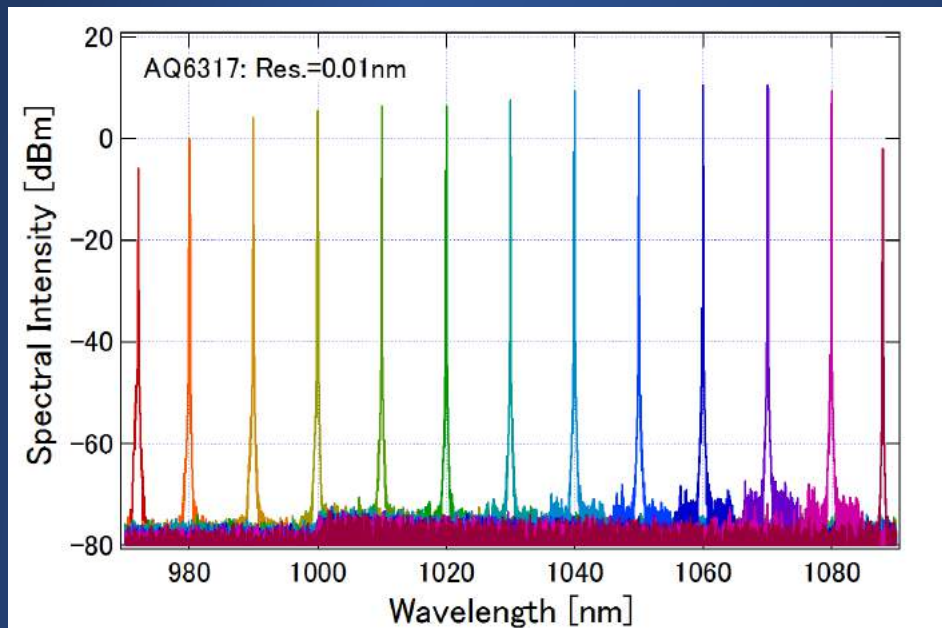
Air Space Output Type





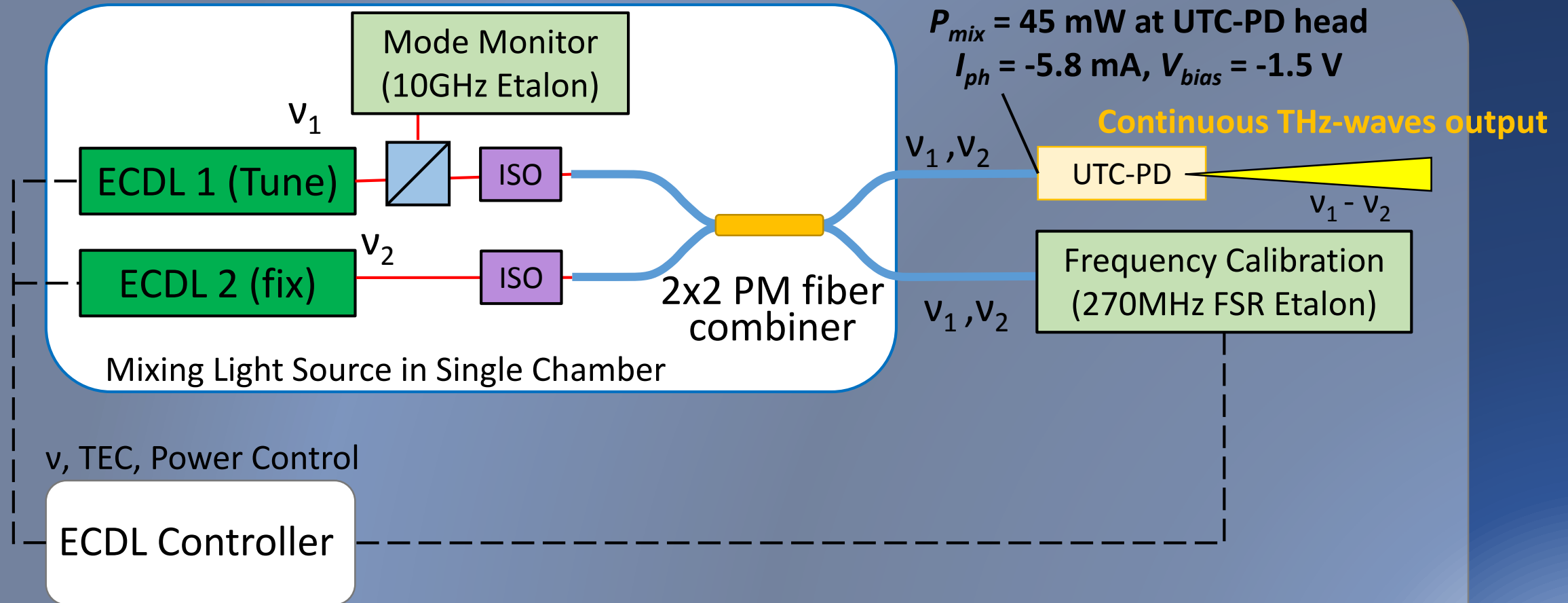
# Our 1 $\mu\text{m}$ -Band External Cavity Diode Laser $\Lambda$ -Master 1040 is used as Mixing Light Sources

- High Power **ASE-Free** Output : 50 mW
- Wide-Band **Mode-Hop-Free** Tuning : 50 nm
- Ultra High Resolution Control : 0.01 pm



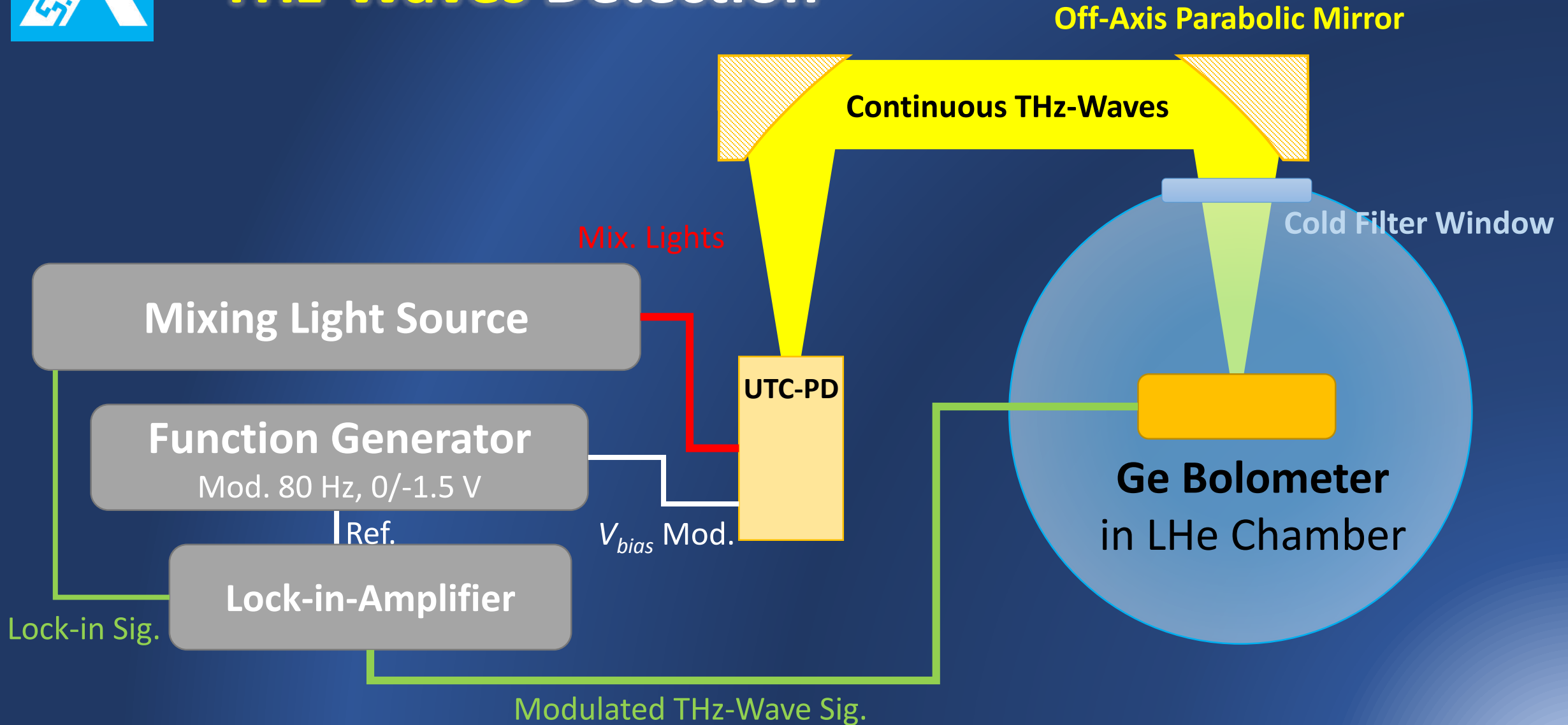


# Outline of THz Light Source



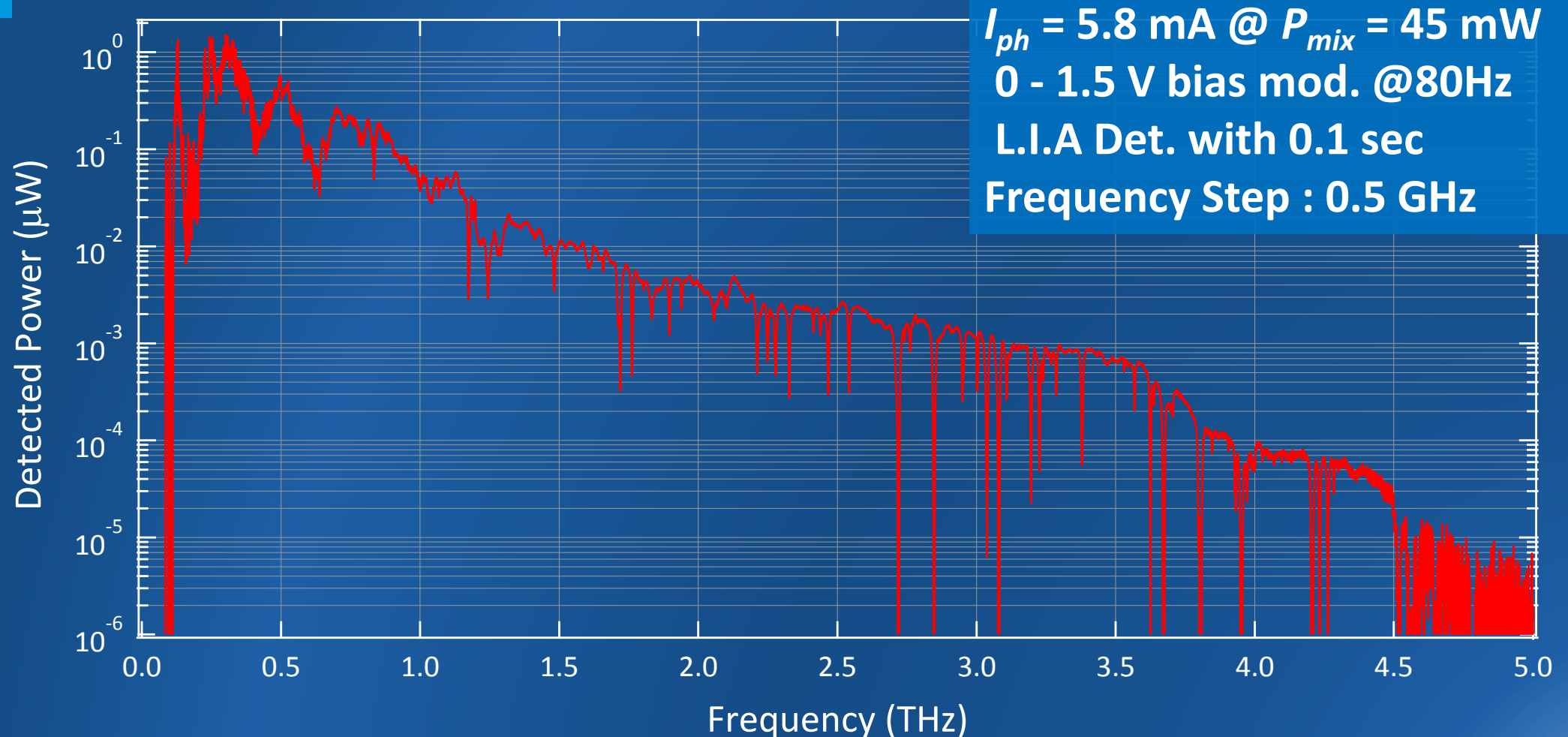


# THz-Waves Detection





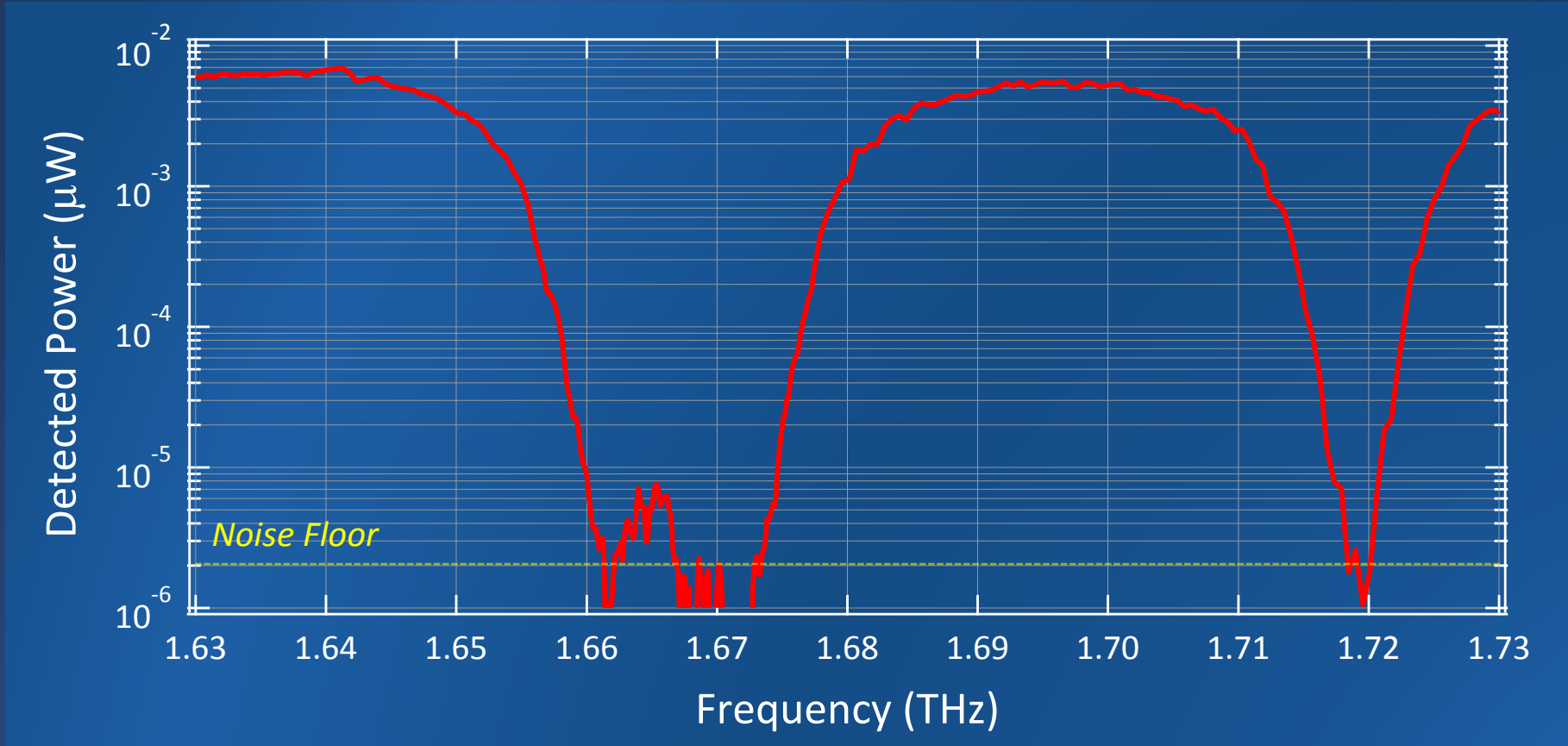
# Emission Spectra from UTP-PD Photo-Mixer



- THz-Waves Emission is observed up to 4.5 THz
- 100 nW at 0.9 THz, 1 nW at 3 THz



# High Resolution Measurement of Water Vapor Absorption

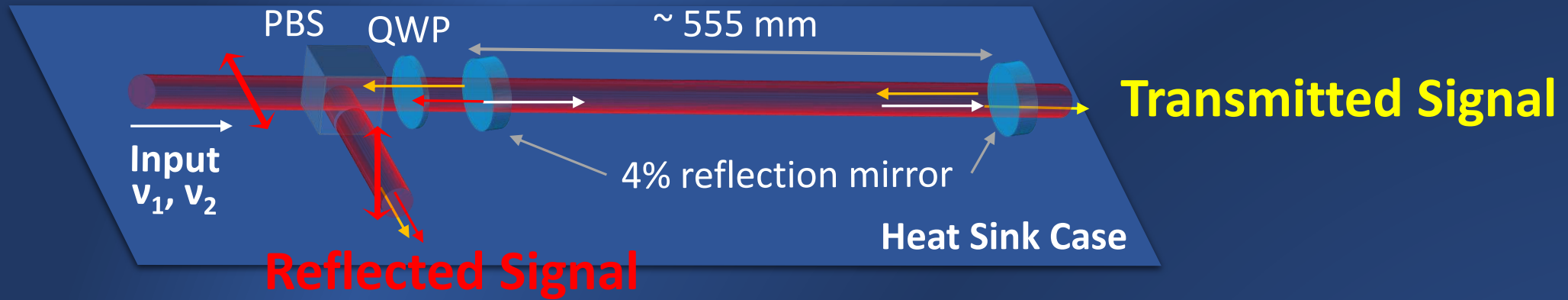


- Dynamic range reaches 40 dB (in power ratio) against  $\sim 2$  pW Noise Floor.  
→ may be ascribed to ASE-free mixing light source.



# Frequency Calibration

270 MHz FSR (555 mm) ;  $\alpha = 1.2 \times 10^{-6} / ^\circ\text{C}$

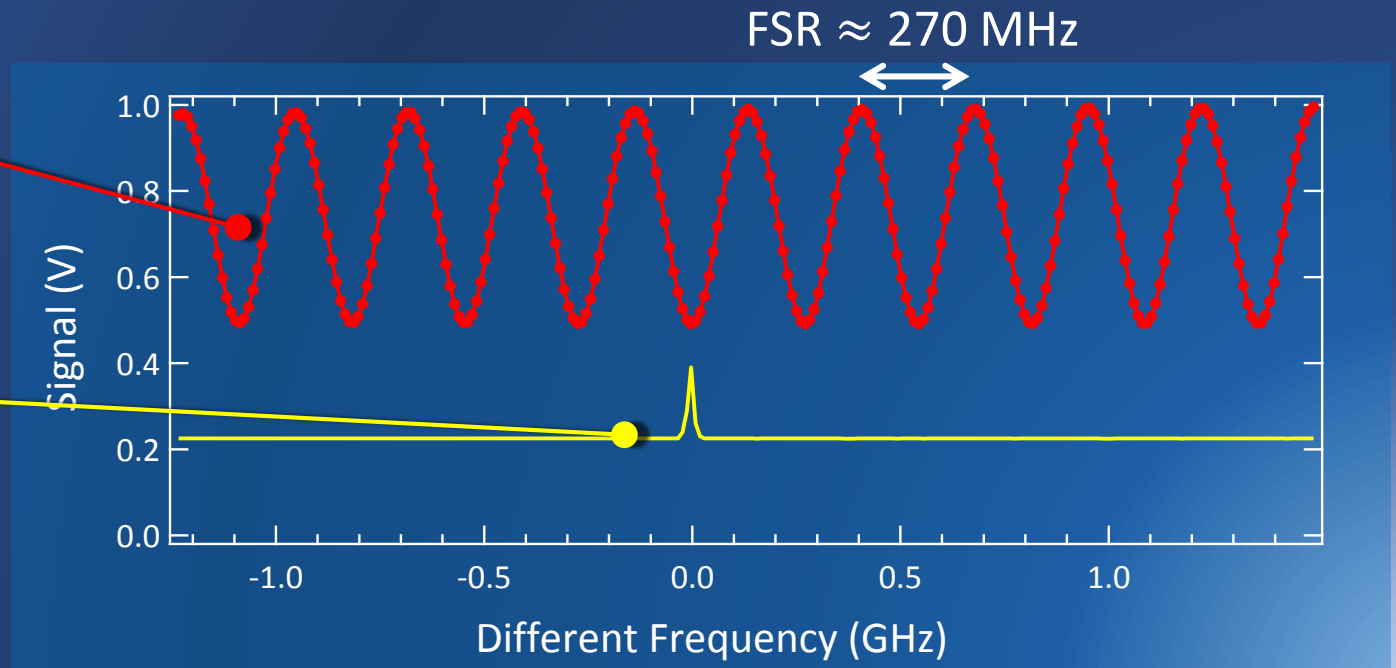


## Etalon Interference Fringe

$v_1, v_2$  locked at Dark/Bright Fringe

## RF Noise at $v_1 = v_2$

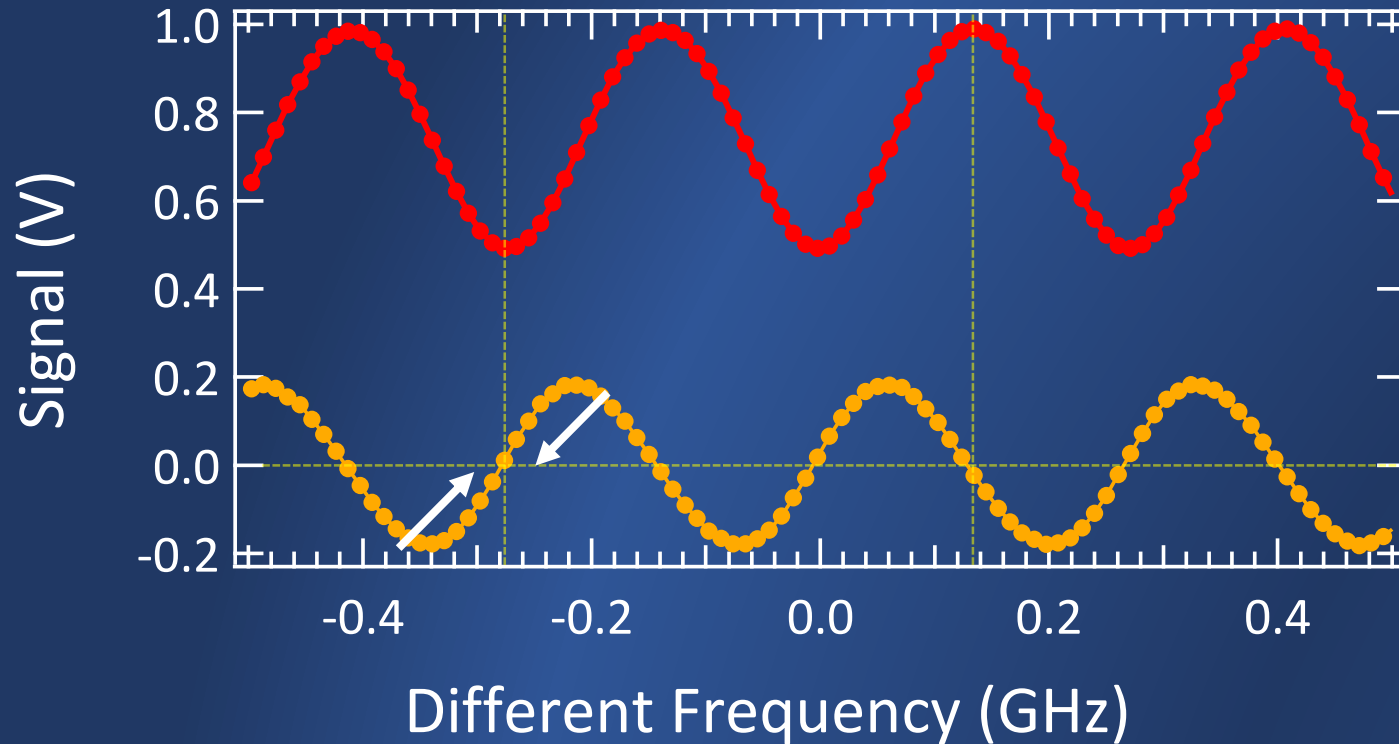
Difference Frequency "Zero Point"







# Duel Frequency Locking



**Etalon Interference Signal**

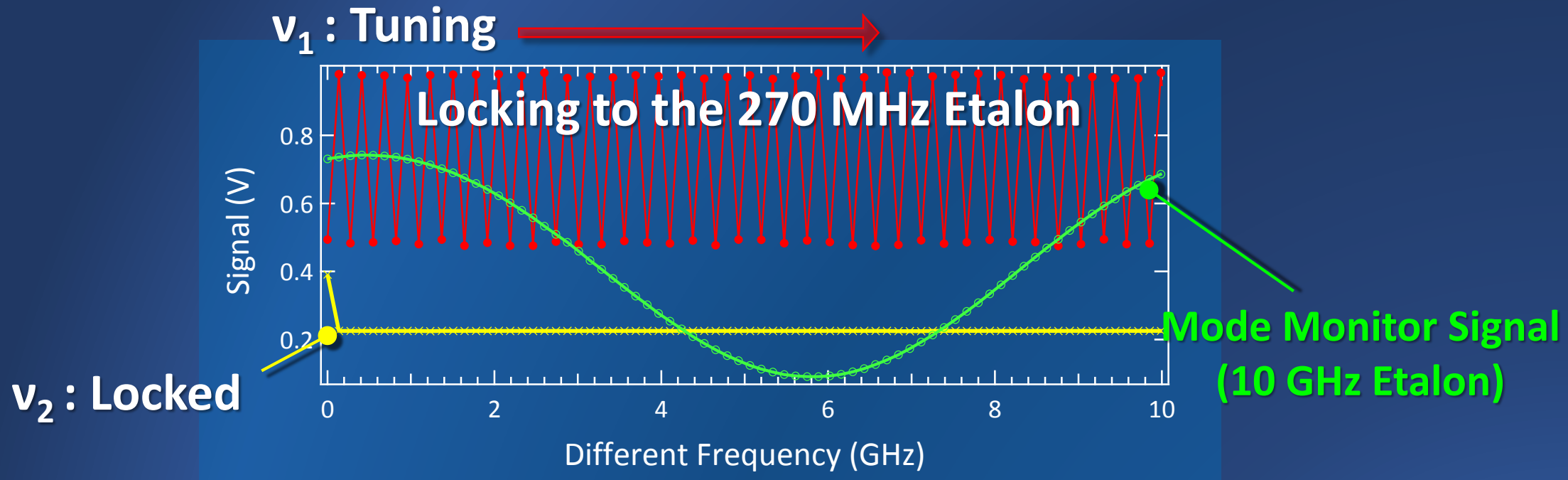
**Error Signal  
by Current Modulation**


- Mixing frequencies are locked into an Etalon  
by using error signal with current modulation.

Modulation frequency : 10 kHz ( $\nu_1$ ), 1 kHz ( $\nu_2$ )  
Modulation Amplitude : 20 MHz (0.5 mA)



# Difference Frequency Tuning under Dual Frequency Locking



- Fixed ECDL ( $\nu_2$ ) is locked at a fixed mode.
- Tuning ECDL ( $\nu_1$ ) is scanned, and locked at fringe by fringe.
  - **Beat noise** at  $\nu_1 \approx \nu_2$   Indicates **Zero Point** of Difference Frequency
  - Data are obtained at each **fringe** with an accuracy of etalon FSR estimation error.



# Etalon FSR Estimation

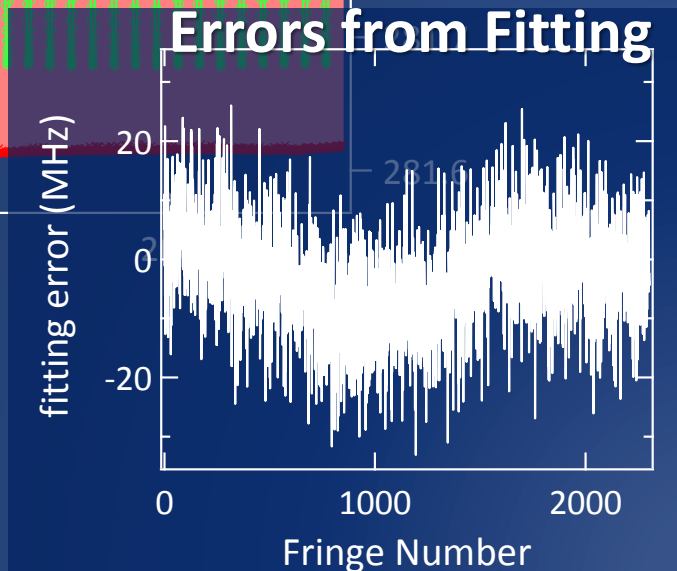
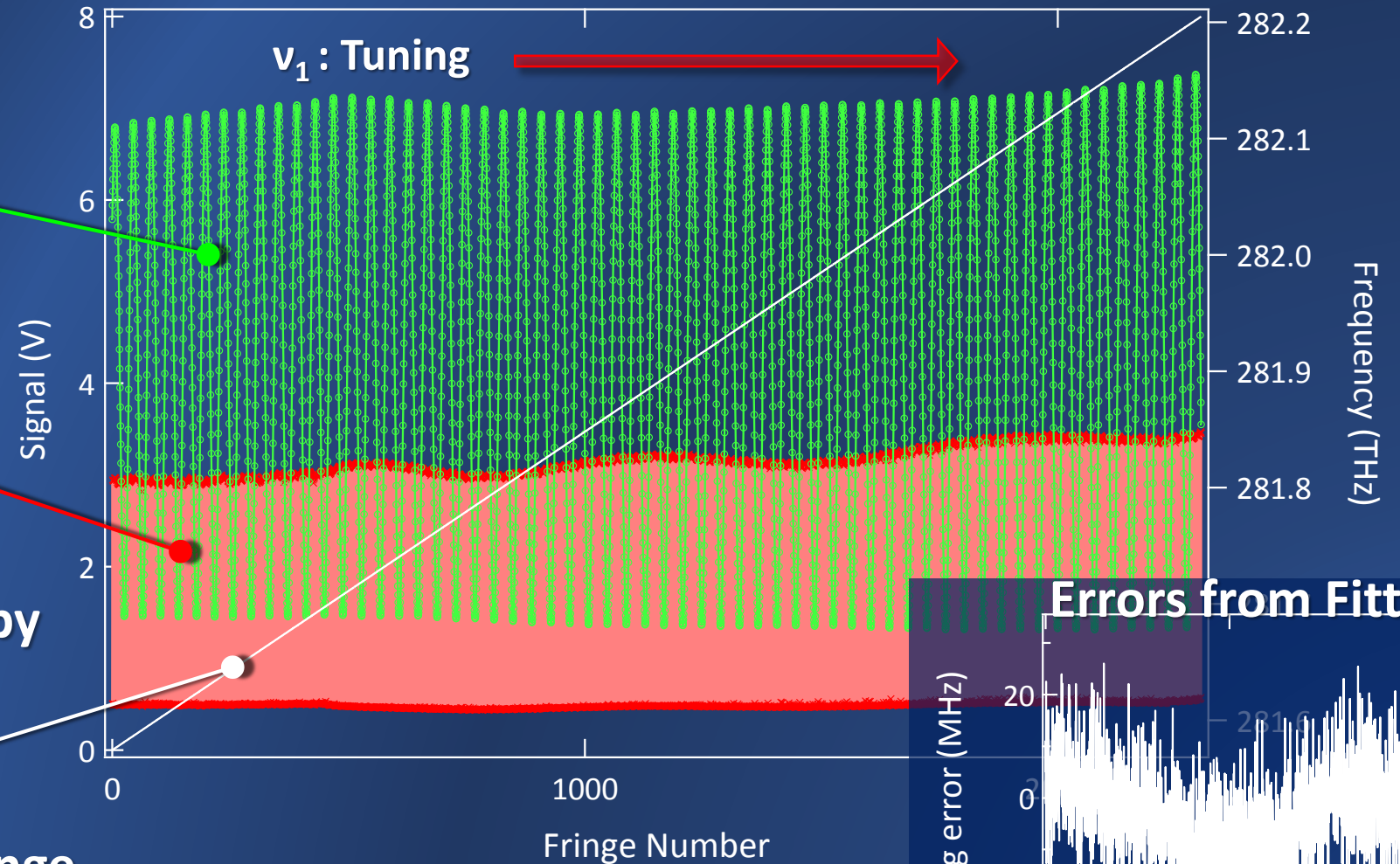
Mode Monitor Signal  
(10 GHz Etalon)

Frequency Calibration Signal  
(270 MHz Etalon)

Frequency ( $\nu_1$ ) obtained by  
Wavelength meter  
(771A-NIR, Bristol)

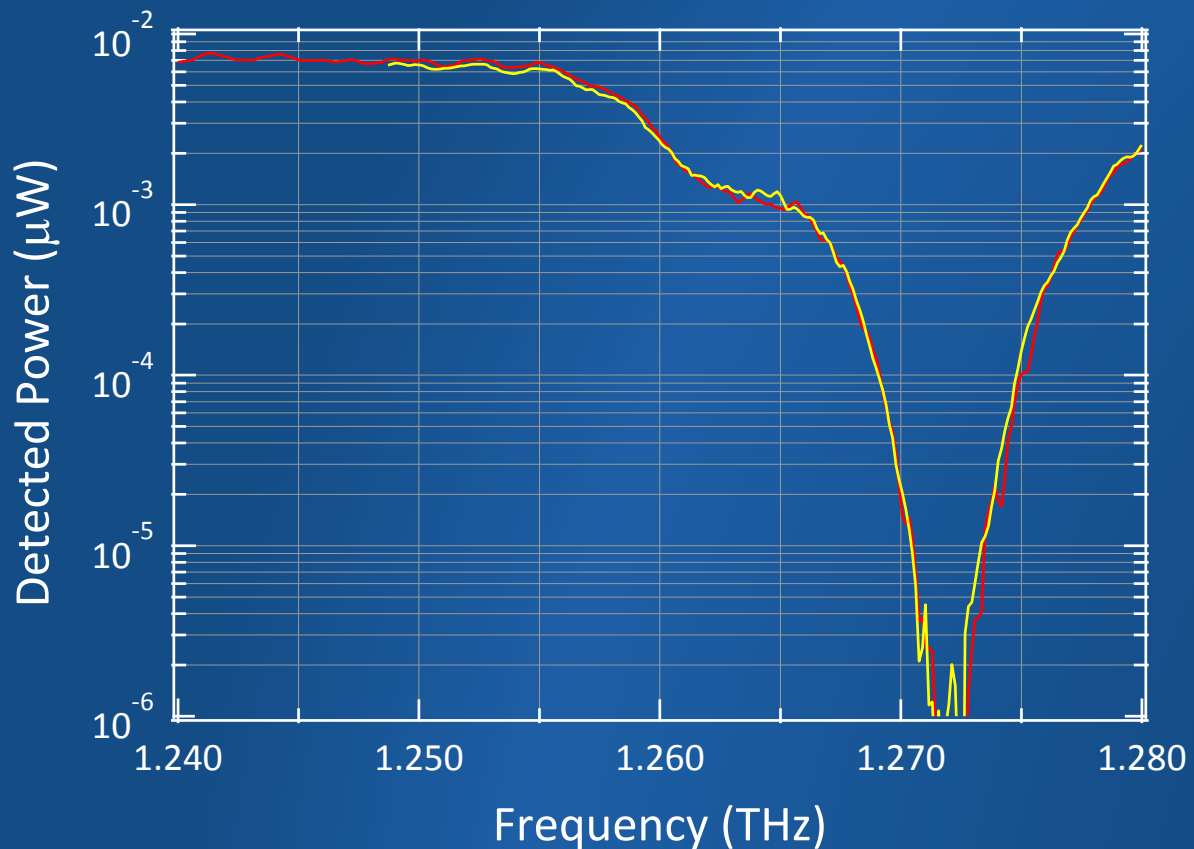
Slope = 0.2736812 GHz/Fringe

**FSR = 0.2736812 GHz** (Estimation error is  $1 \times 10^{-7}$  GHz)

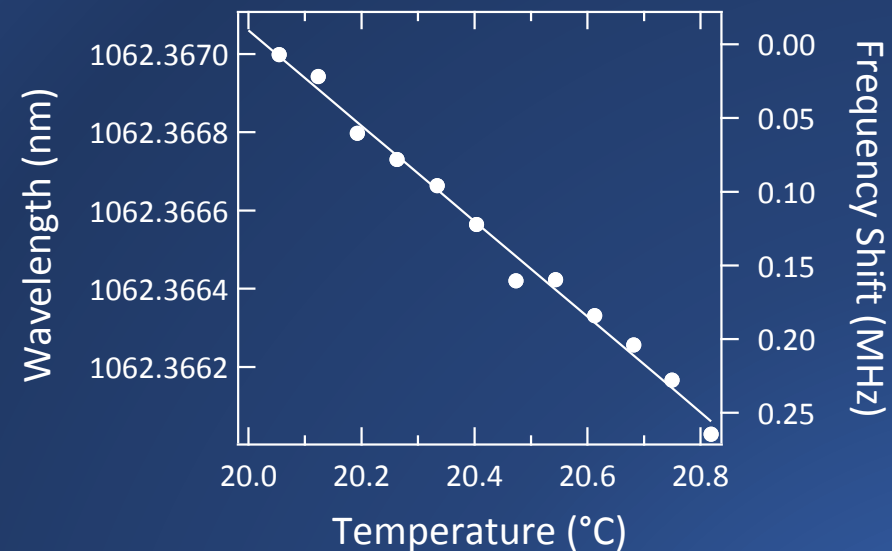




# Frequency Resettable Tuning



— First scan  
— Second scan



Thermal Change Ratio of FSR =  $1.15 \times 10^{-6}/^{\circ}\text{C}$   
 $\approx \alpha_{invar} (1.2 \times 10^{-6}/^{\circ}\text{C})$

- Twice scans show good agreement.

➔ Frequency Resettable is ascribed to less than 1.2 MHz @ 1 THz



# Summary

**Photomixing with UTC-PD and ASE-Free ECDL ( $\lambda$ -Master) Provides**

- **Wide-Tuning Range : 4.5 THz**
- **High Resolution Frequency Control : 3MHz**
- **High-Purity THz-Waves: > 40dB**

**Dual Frequency Locking to an athermal etalon enables**

- **High Accuracy and Resettability Spectroscopy : 1 MHz @ 1 THz**