

The precise temperature control of ball  
SAW sensors for trace moisture  
measurement  
at ppb level of concentration

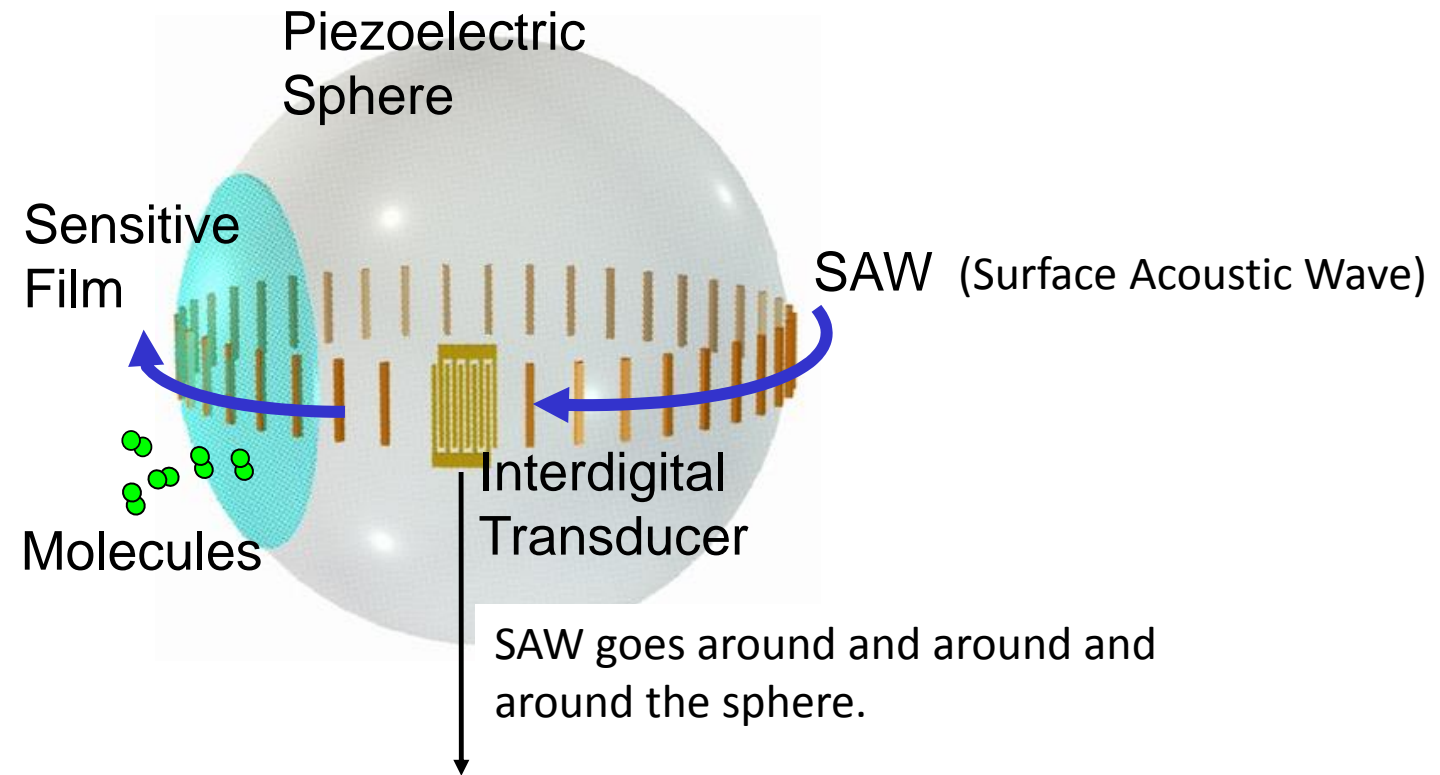
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Ball Wave Inc.

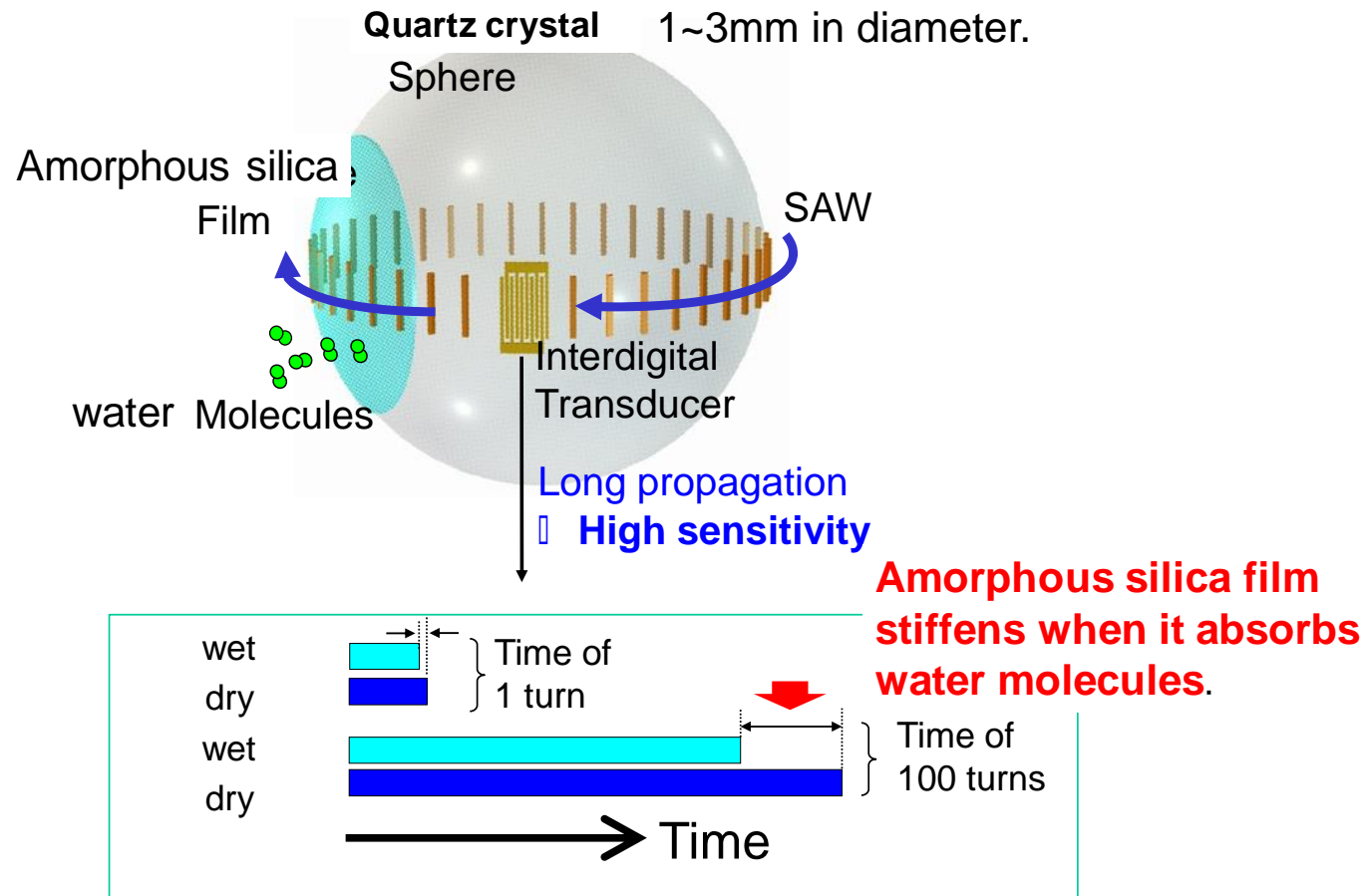
# The ball SAW sensor

- What is the ball SAW sensor?
- How does it measure the trace moisture?
- We had a difficulty caused by temperature variation.
- How did we solve it?
- Our detection limit is about 1ppbV trace moisture in N<sub>2</sub> gas.
- We detect the trace moisture in hydrocarbon gases with a same calibration curve.
- We detect a-few-seconds spikes of trace moisture.

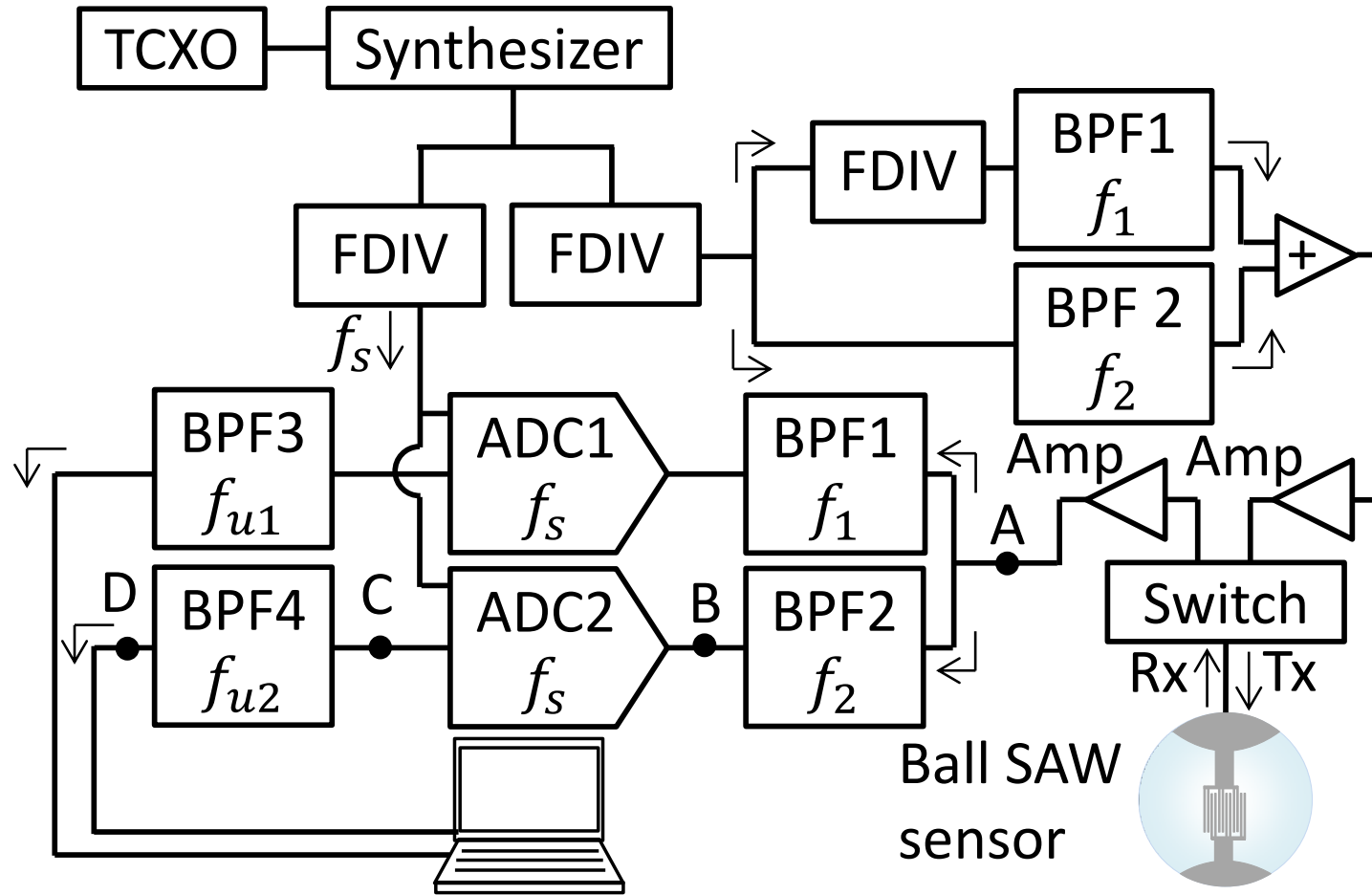
# What is the ball SAW sensor?



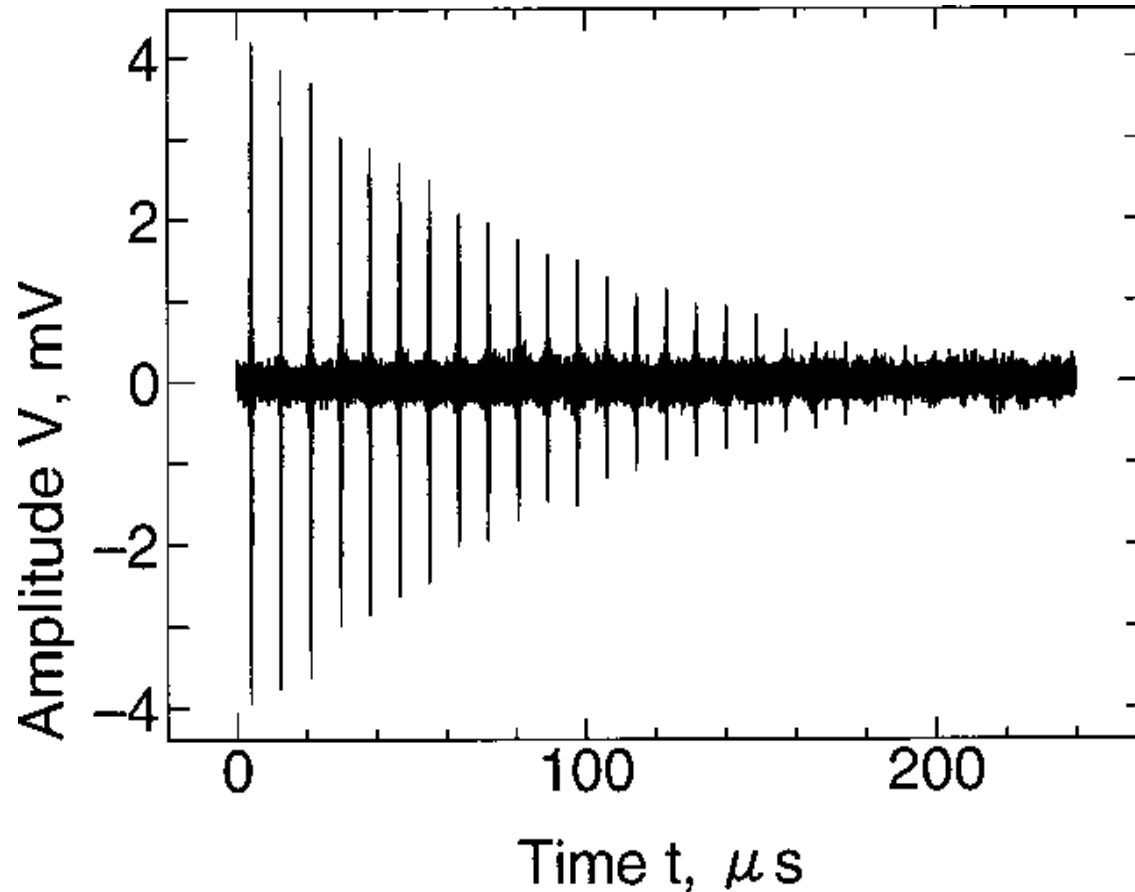
# What is the ball SAW sensor?



# How does it measure the trace moisture?



# How does it measure the trace moisture?



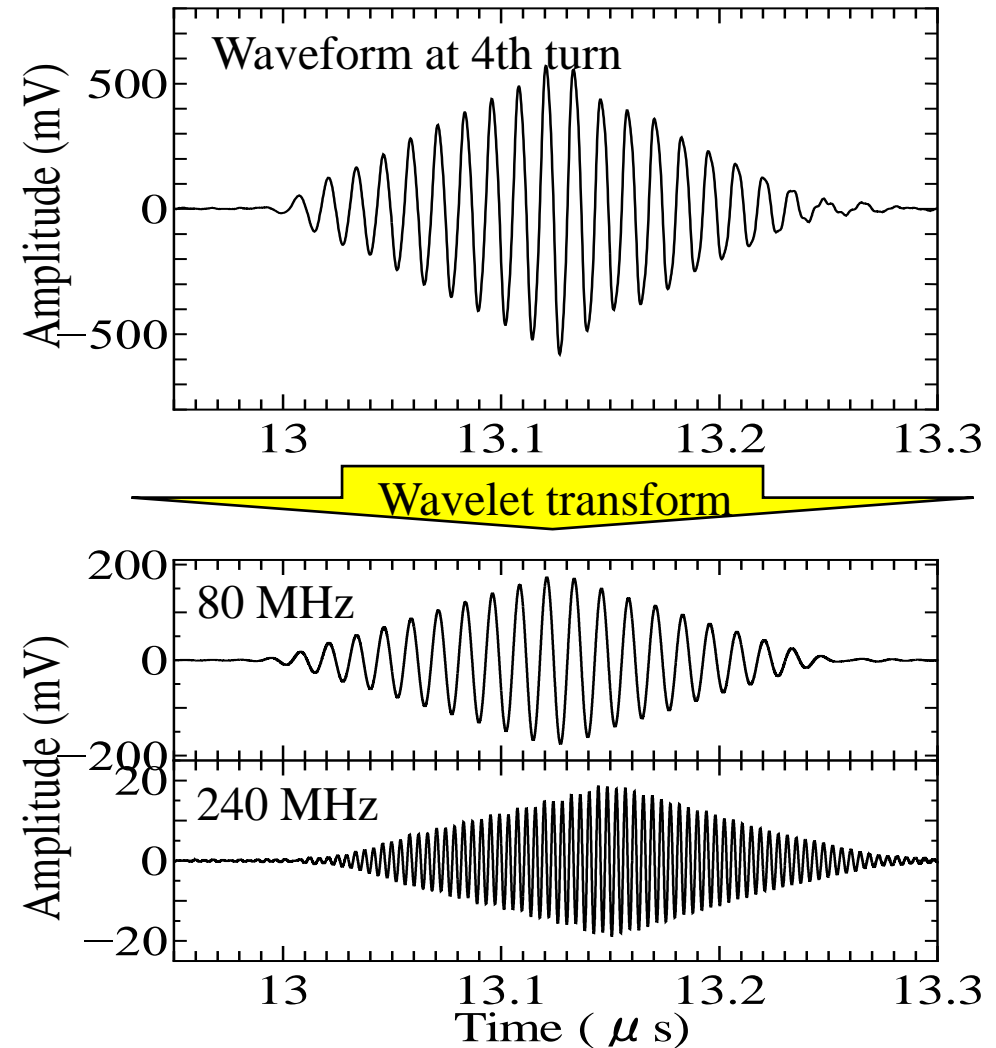
We measure  
(1) the decay rate and  
(2) delay-time of pulses.

# Difficulty caused by temperature variation.

- We have to measure the ppm level of change in the delay-time of pulses.
- But the delay-time strongly depends on temperature.
- We need to compensate it for the trace moisture detection at ppbV level.

# How did we solve it?

We use two frequencies to compensate for the temperature variation.





# How did we solve it?

Relative delay time changes at frequencies  $f_1$  and  $f_2$ , are given by

$$Dt_1 = B(T) f_1 G(w) + A_1(T - T_{\text{REF}})$$

$$Dt_2 = B(T) f_2 G(w) + A_2(T - T_{\text{REF}})$$

where  $w$  and  $T$  are moisture concentration and temperature, respectively.

From these equations, we obtain

$$Dt_w = Dt_2 - CDt_1 = (f_2 - Cf_1)B(T)G(w)$$

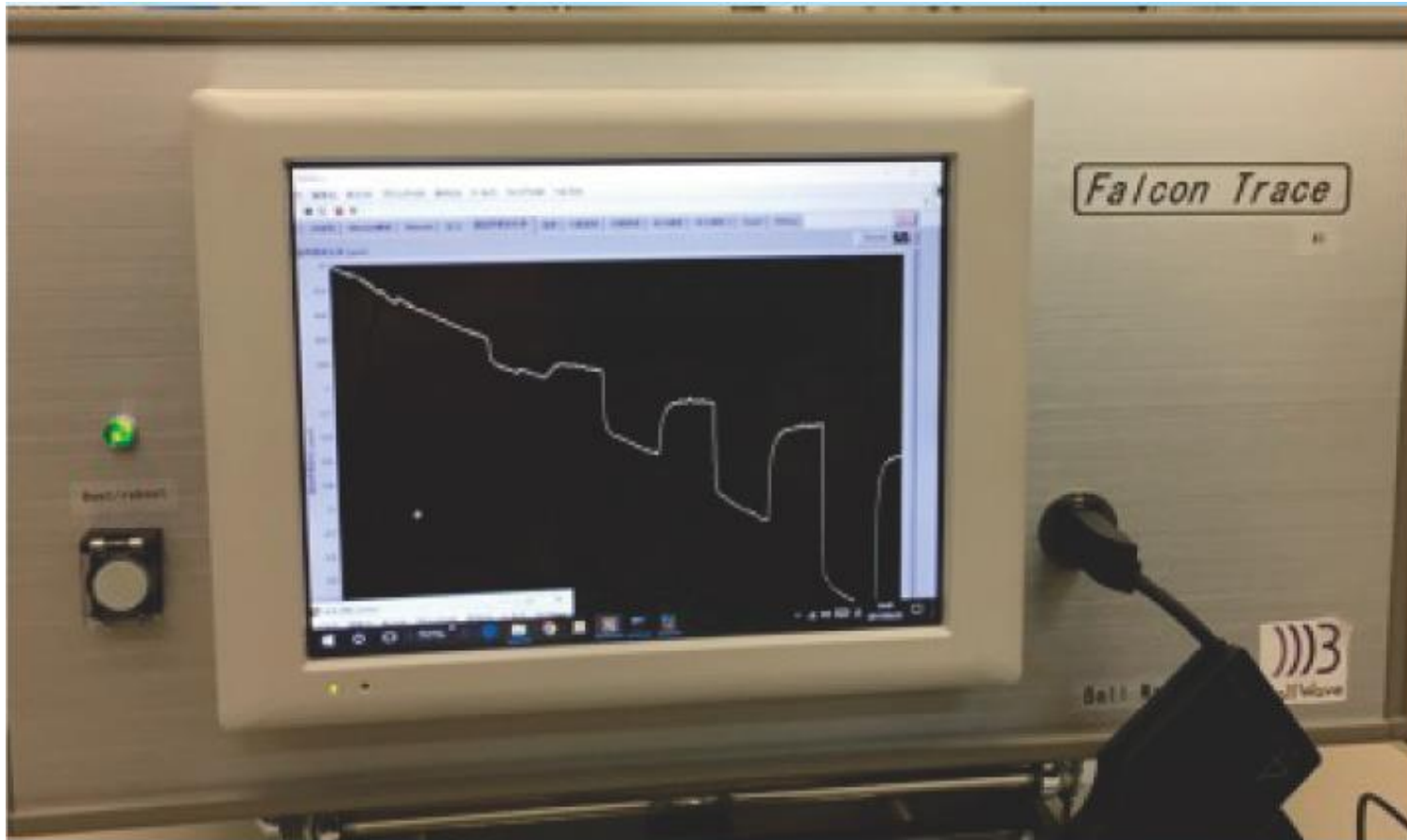
$$Dt_T = A_1(T - T_{\text{REF}}) = \frac{(f_2 / f_1)Dt_1 - Dt_2}{(f_2 / f_1) - C}$$

where  $(f_2 - Cf_1)B(T) = a \exp[De / k_B(T + 273)]$   
and  $C = A_2 / A_1$ .

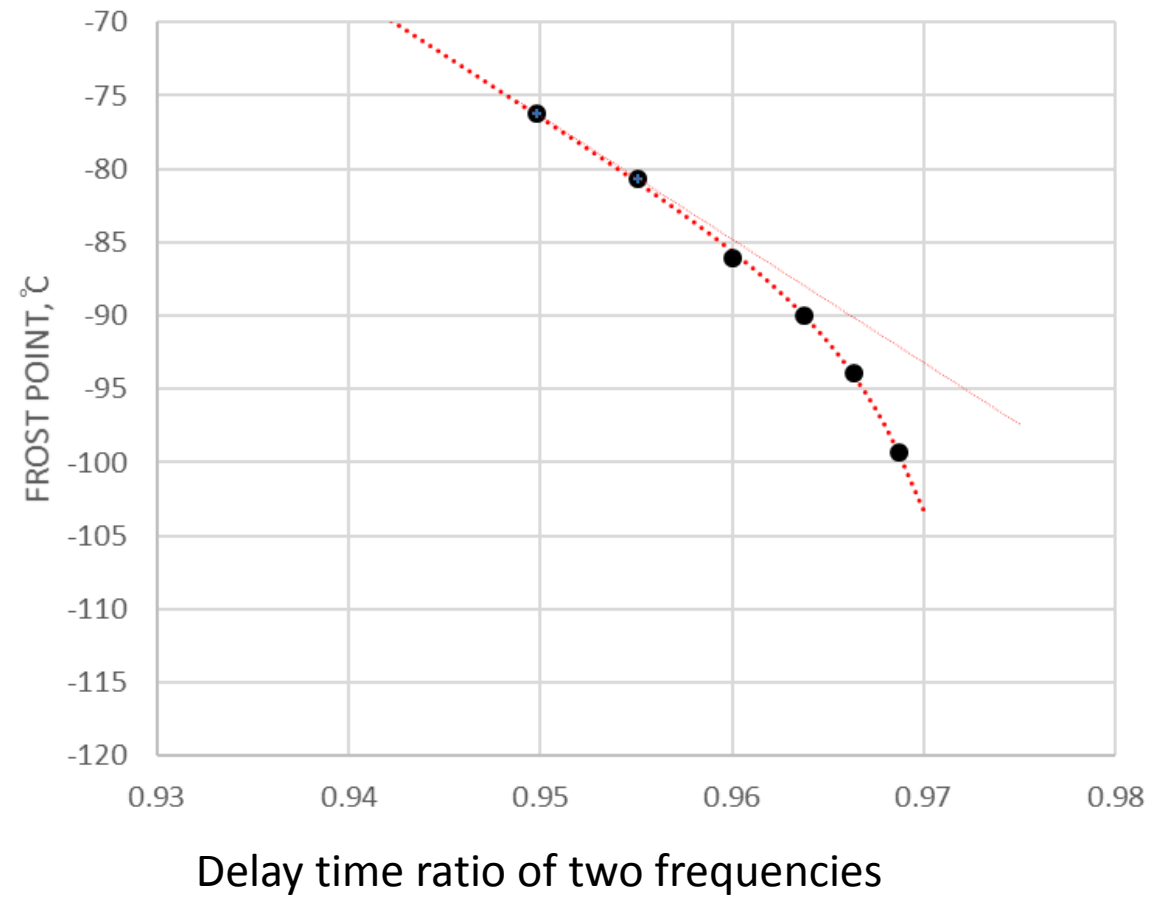
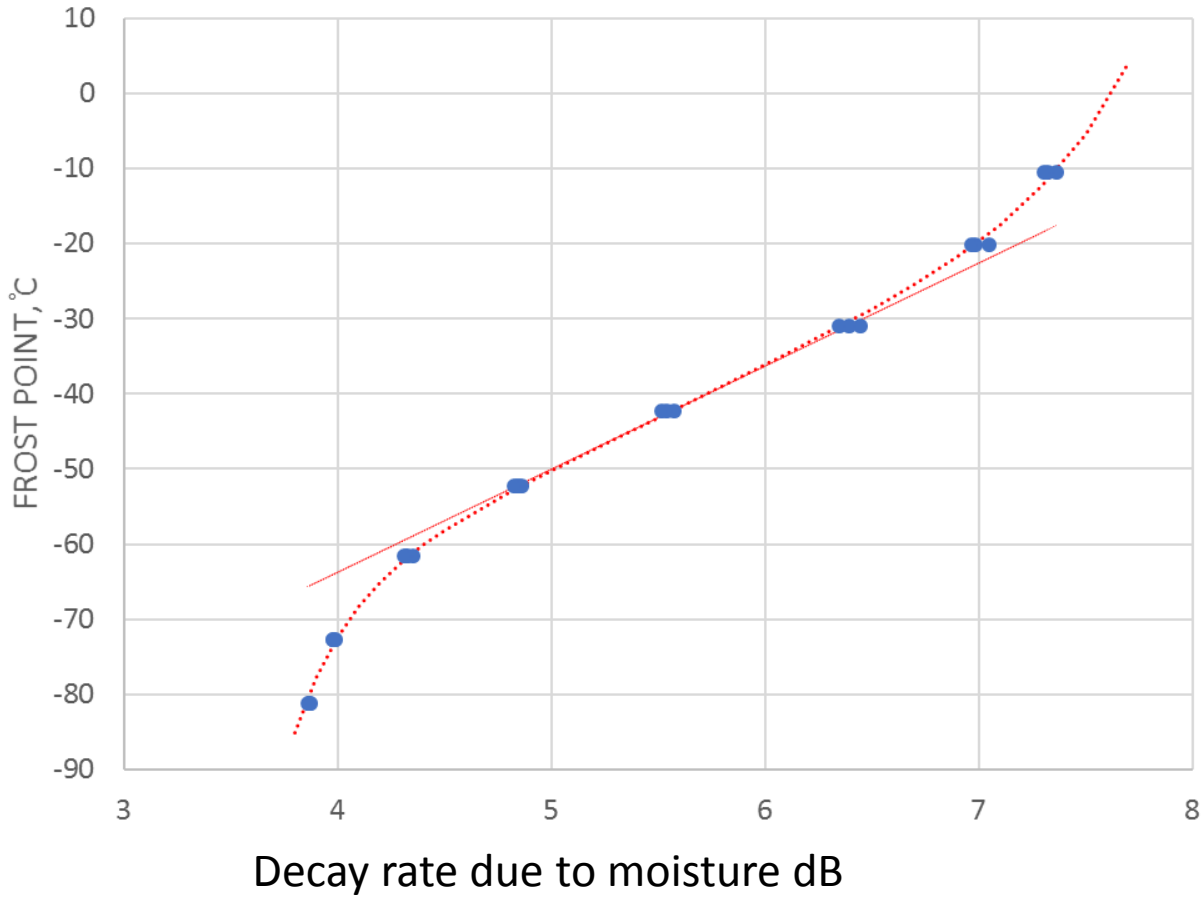
Ref: Proceedings of Symposium on Ultrasonic Electronics, Vol. 37 (2016) 16-18 November, 2016

# *Falcon Trace* (code name)

We implemented the method in a prototype.

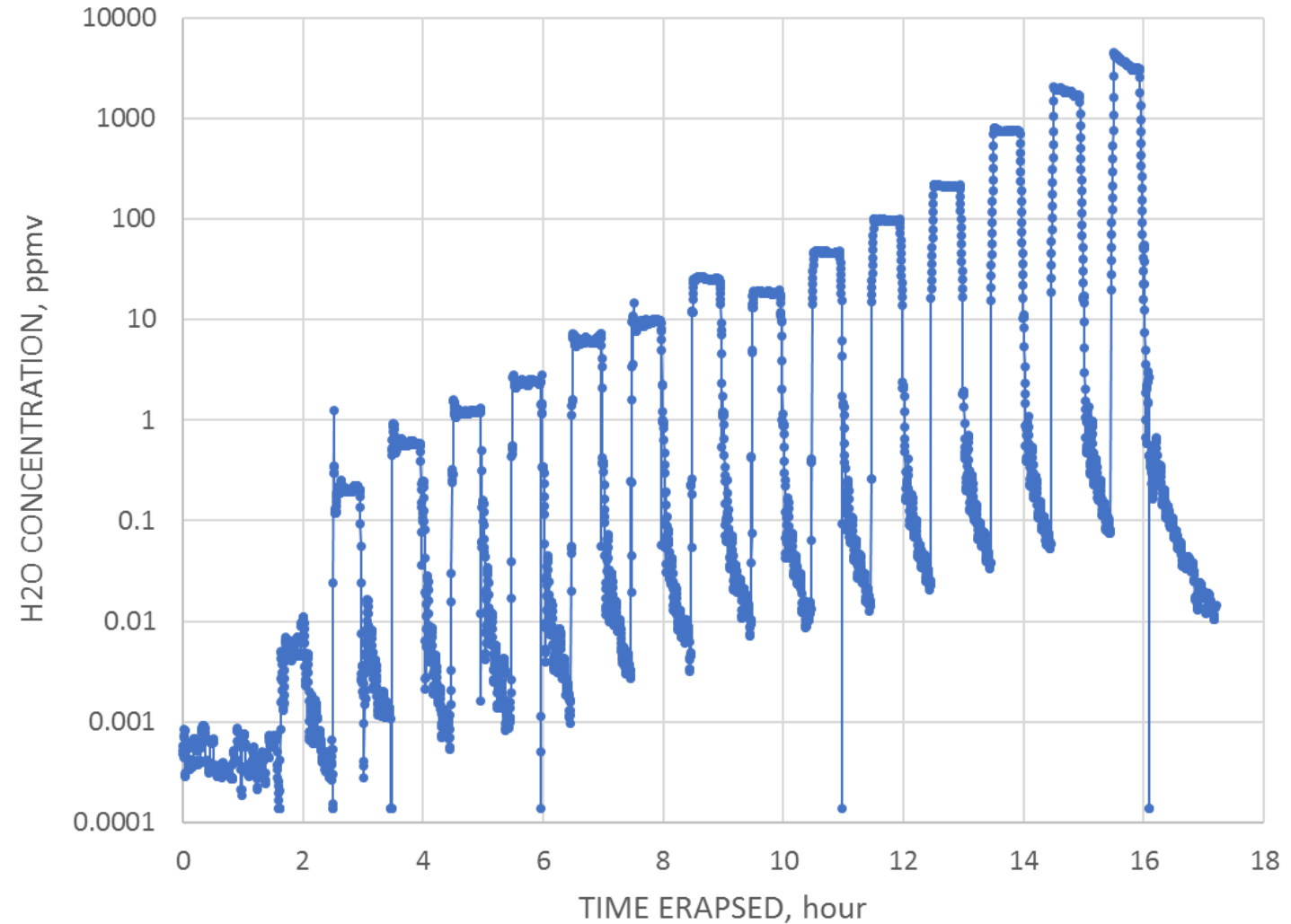


# Our calibration curves for high end and low end



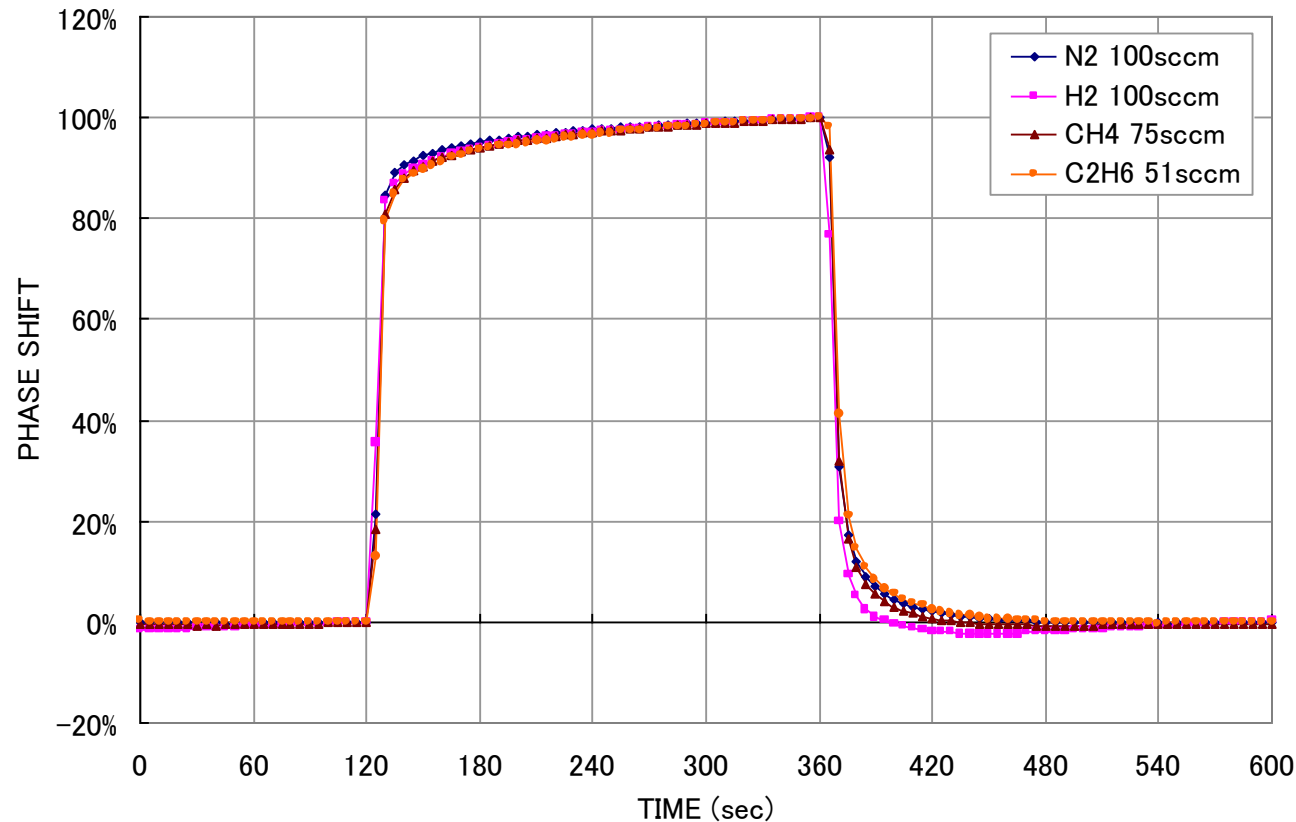
# Our detection limit is about 1ppbV.

Trace moisture measurement  
in the nitrogen gas



# Trace moisture in hydrocarbon gases.

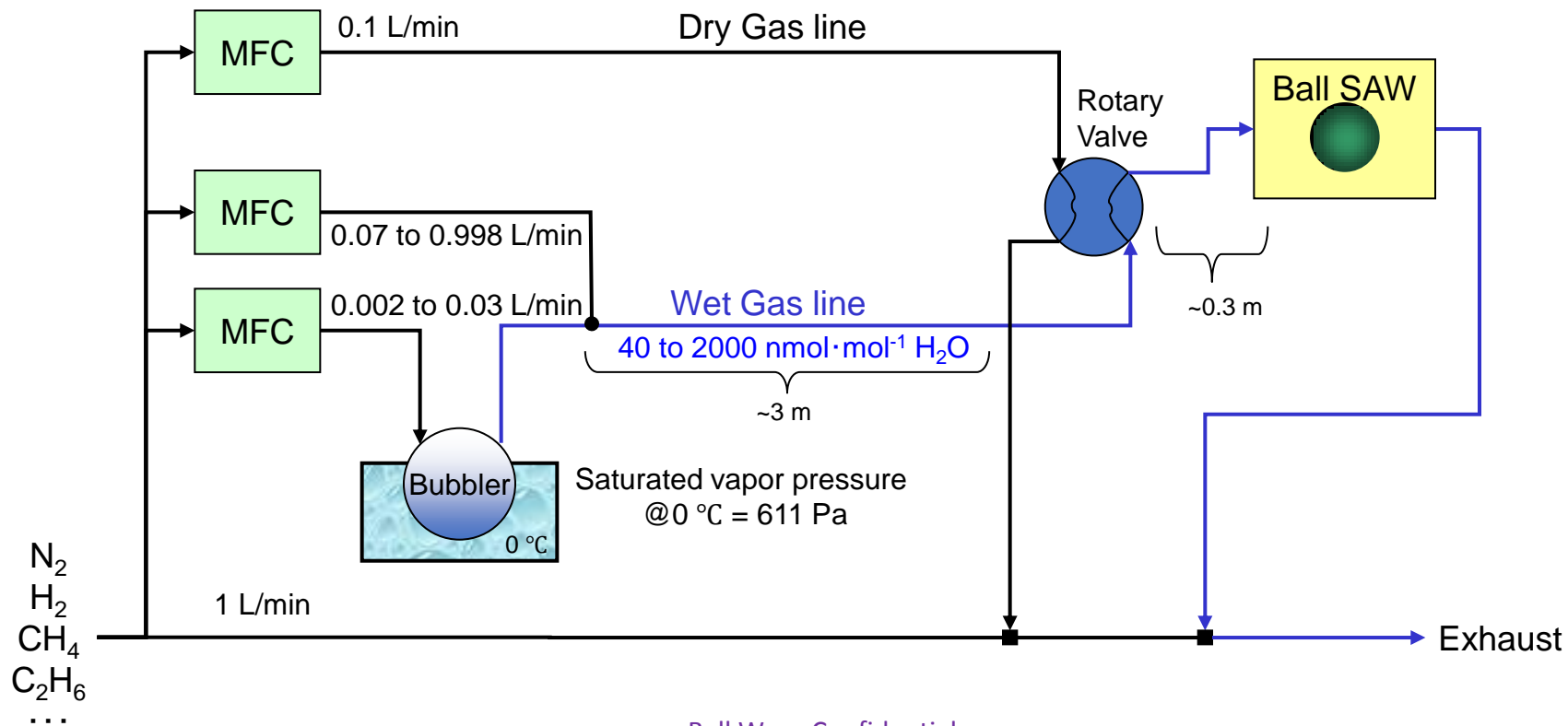
- It works in hydrocarbon gases with the same calibration curve.



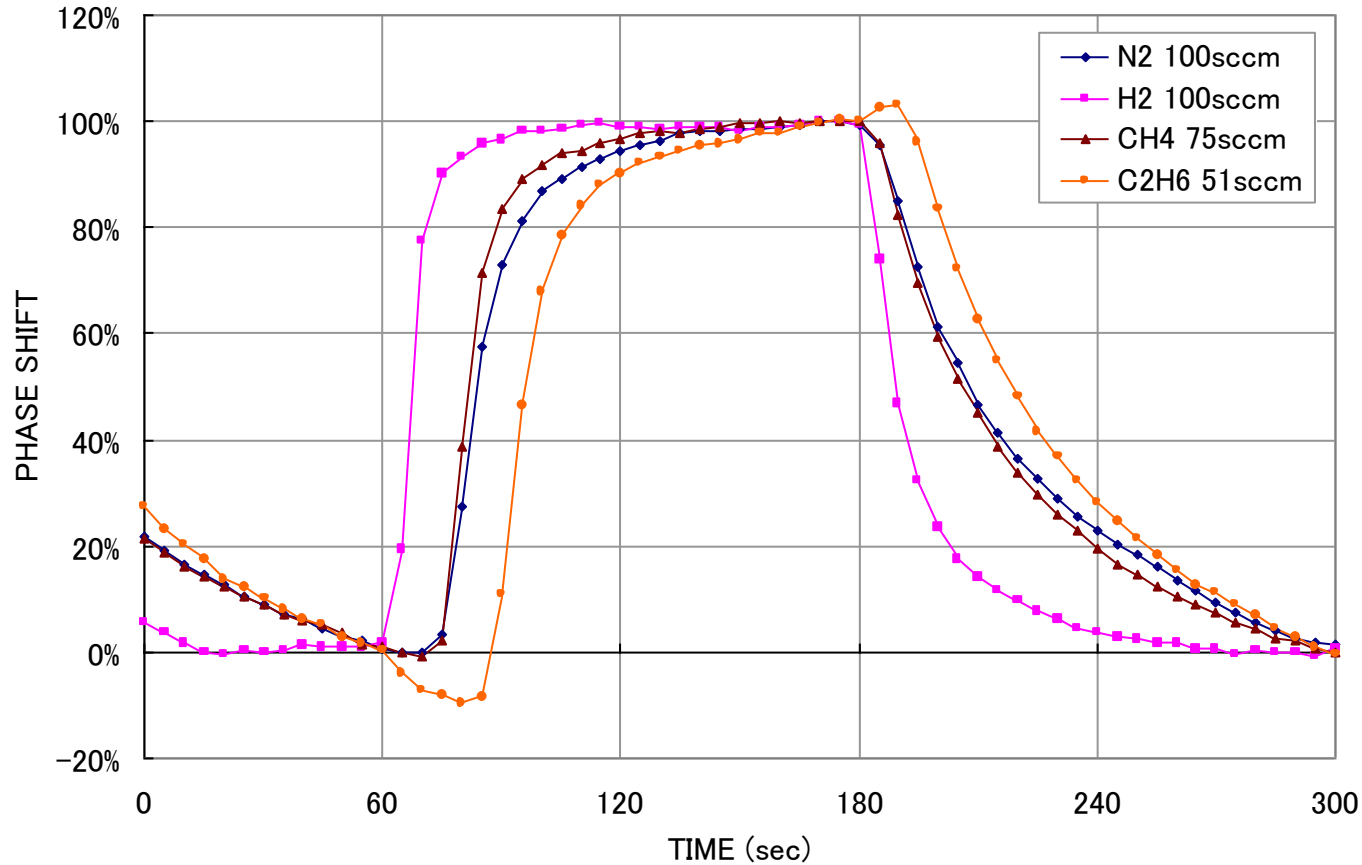
Transient Characteristics  
@ 1,800ppm H<sub>2</sub>O Injection

# Trace moisture in hydrocarbon gases.

## H<sub>2</sub>O Vapor Generation Case 1: Bubbler Method



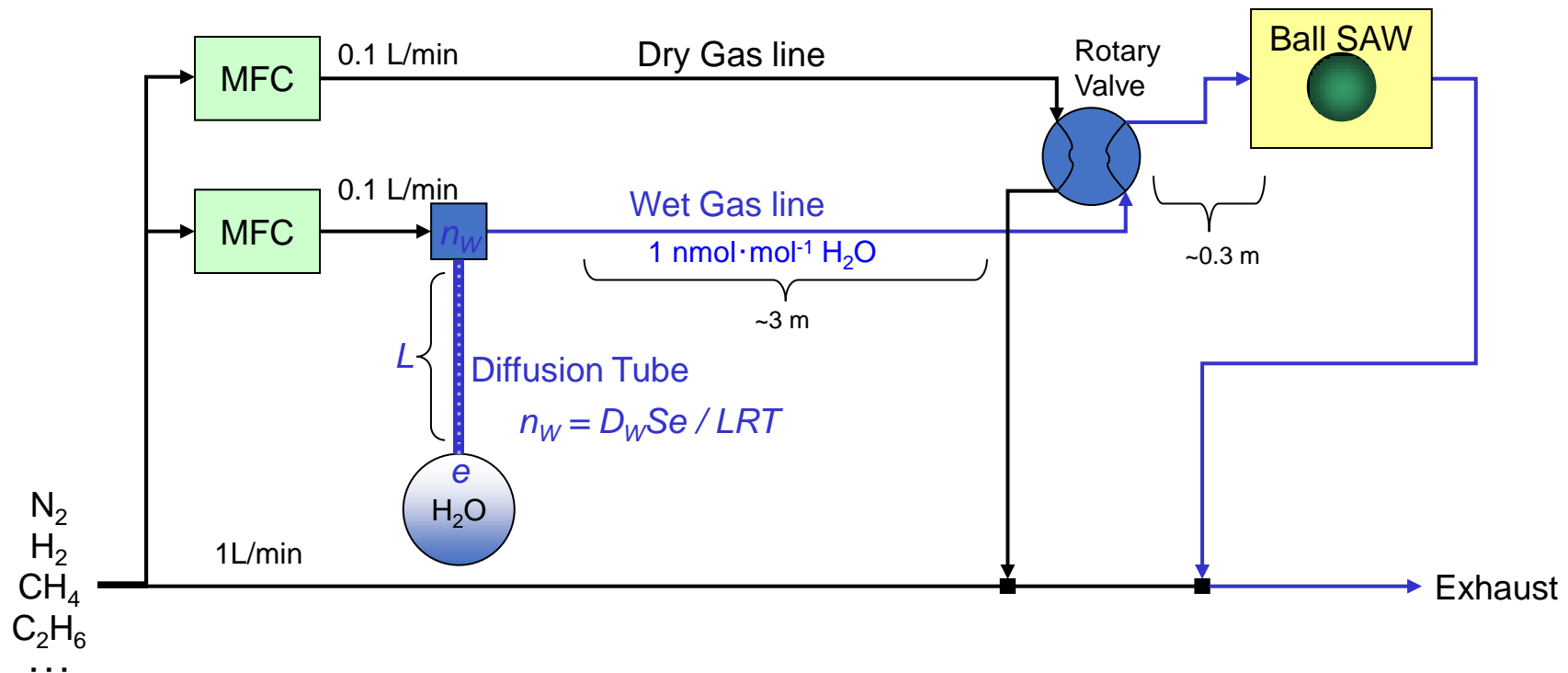
# Trace moisture in hydrocarbon gases.



Transient Characteristics  
@ 1ppm H<sub>2</sub>O Injection

# Trace moisture in hydrocarbon gases.

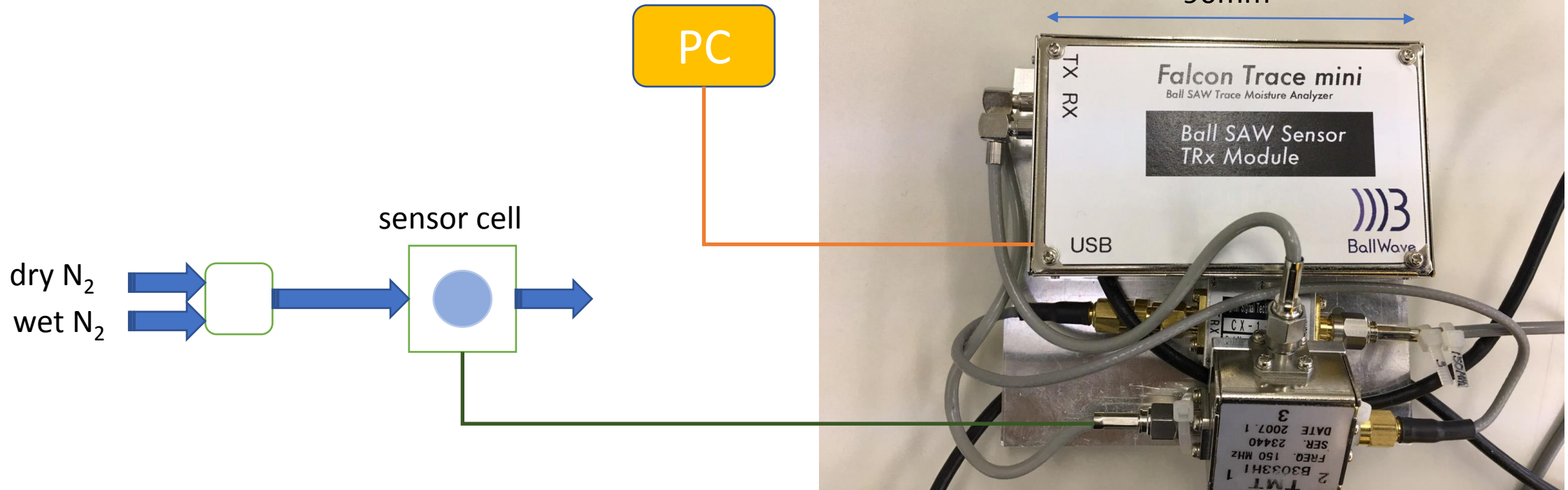
## H<sub>2</sub>O Vapor Generation Case 2: Diffusion Tube Method





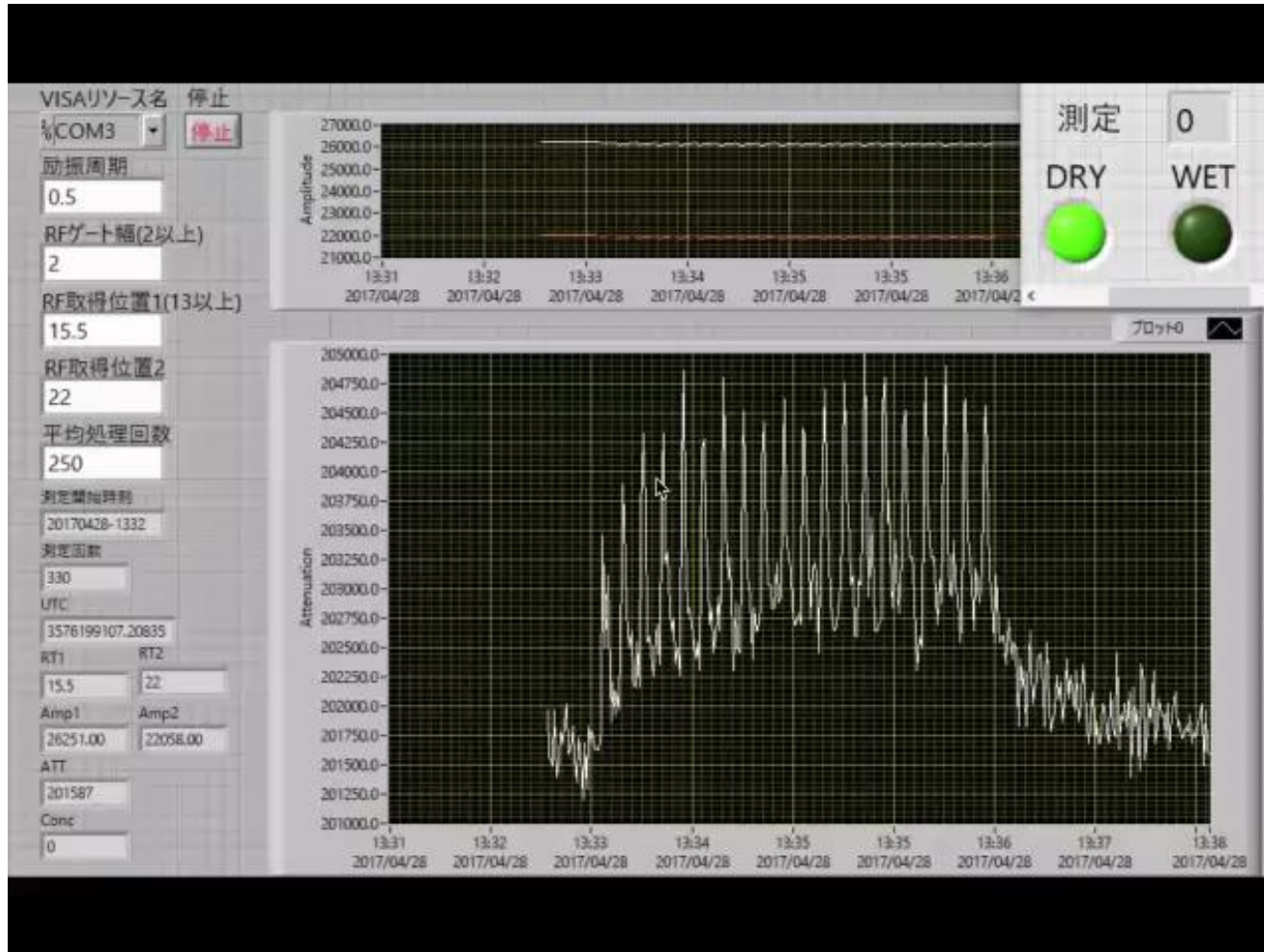
# A-few-seconds spikes in the trace moisture.

- Injected dry N<sub>2</sub> gas and 10ppmv wet N<sub>2</sub> gas alternatively in **5 seconds** into the sensor cell.



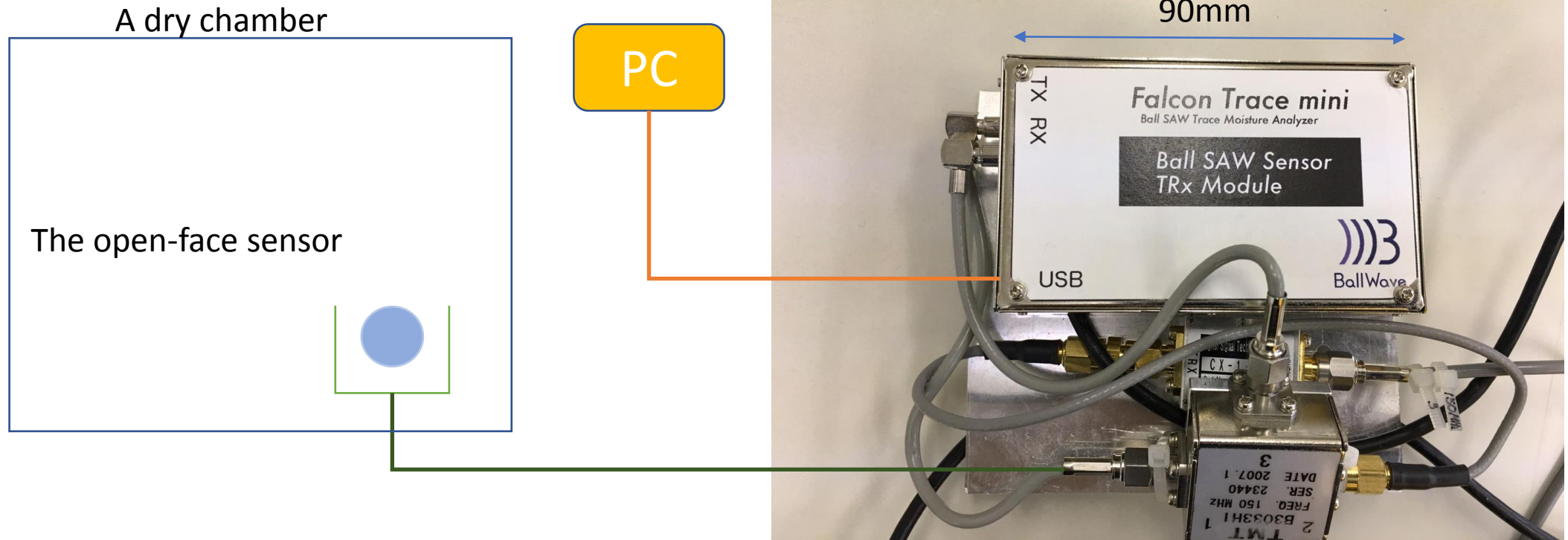
# A-few-seconds spikes in the trace moisture.

Background is not an artifact but is due to the adsorption of moisture on the inner surface of piping.



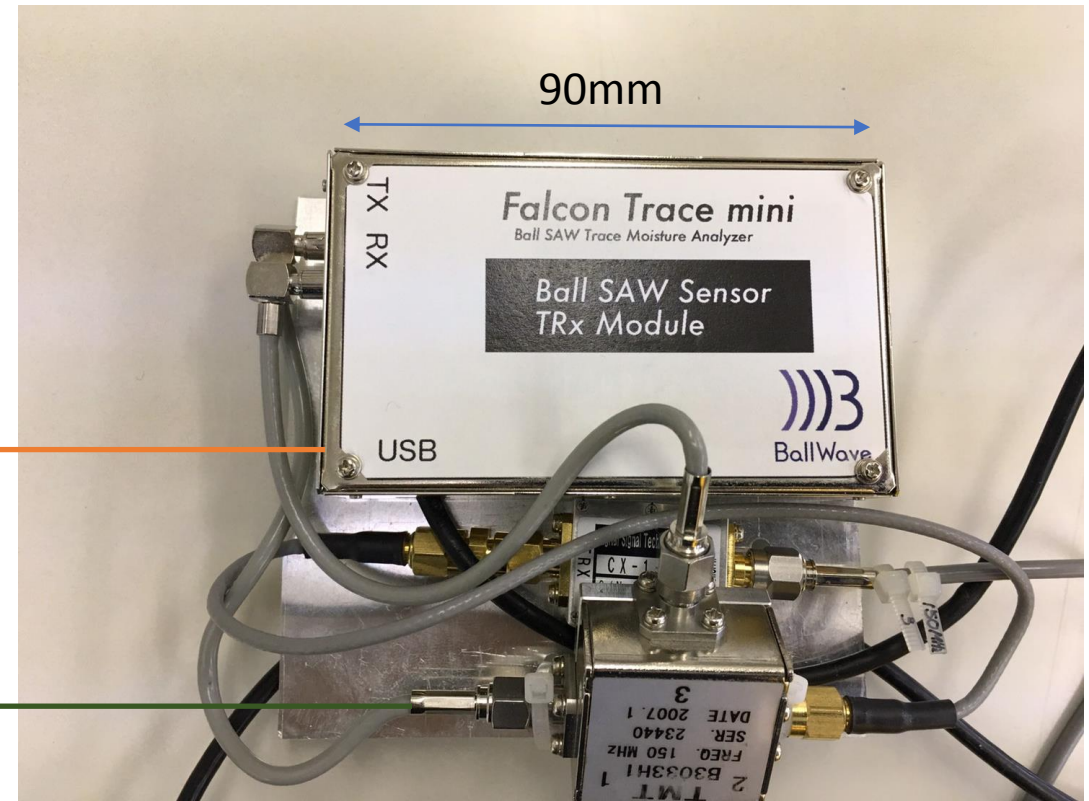
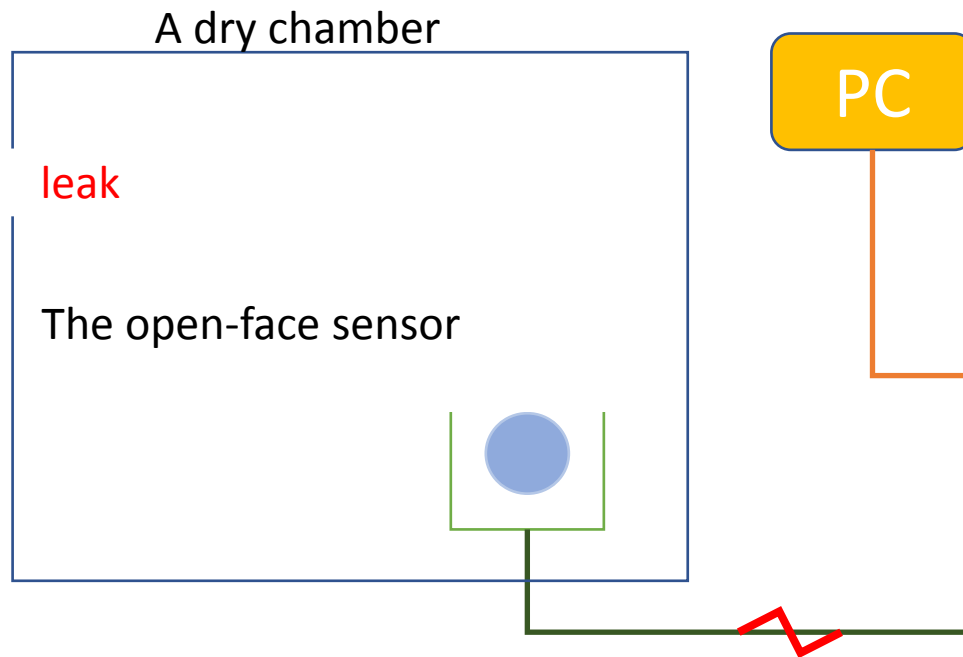
# A-few-seconds spikes in the trace moisture.

The ball SAW sensor works with 0 flow rate.



# A-few-seconds spikes in the trace moisture.

We can monitor a leakage in a moment.



# Thank you for listening.

- We offer a unique solution for the trace moisture measurement with versatile capabilities.
- A prototype for commercial model is available now for early access.