He3/4 ratio from sound velocity measurement

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Background of the study

Dilution refrigeration is often used for cooling of PT

We want to optimize temperature and cooling power

Monitoring He3/4 ratio is important

System of measurement

- Mass spectrum meter (usually) → Gas sampling is needed (loss of gas)
- Sound velocity measurement → Real time monitoring is possible

Principle of He3/4 ratio determination from sound velocity measurement

Theorem equation of sound velocity in gas

$$V = \sqrt{(\gamma RT/M)}$$

V : sound velocity(m/s) γ : specific heat-ratio
R : gas constant T: temperature (K)
M: averaged molecular weight of gas

→ (fixed temperature condition)

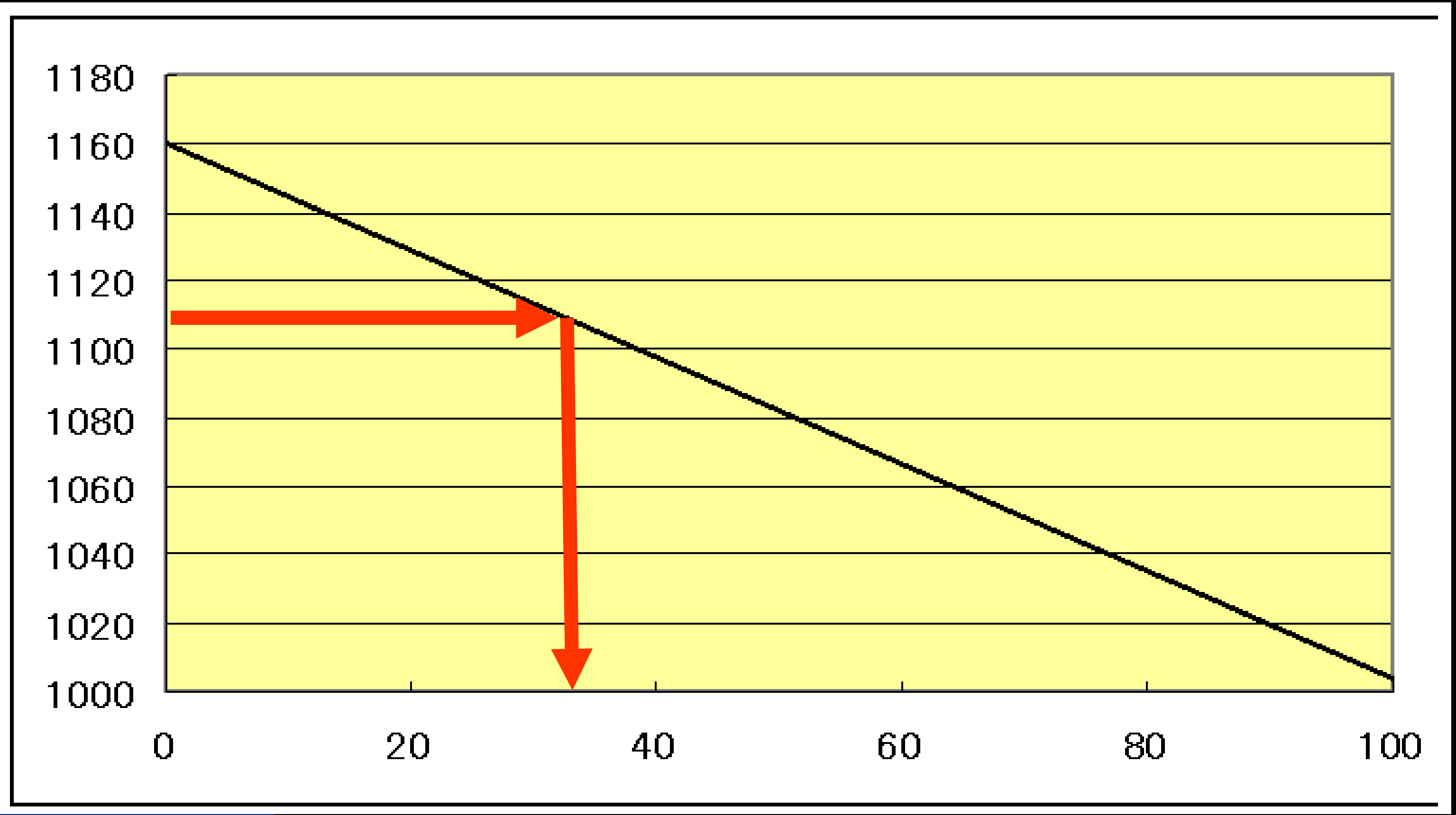
V depends on the contents and the fractions of the mixed gas_

Sound velocity is independent of pressure

Sound velocity of He3/4 mixed gas as a function of ^{4}He fraction

Sound velocity of He3/4 mixed gas (m/s)

T = 22

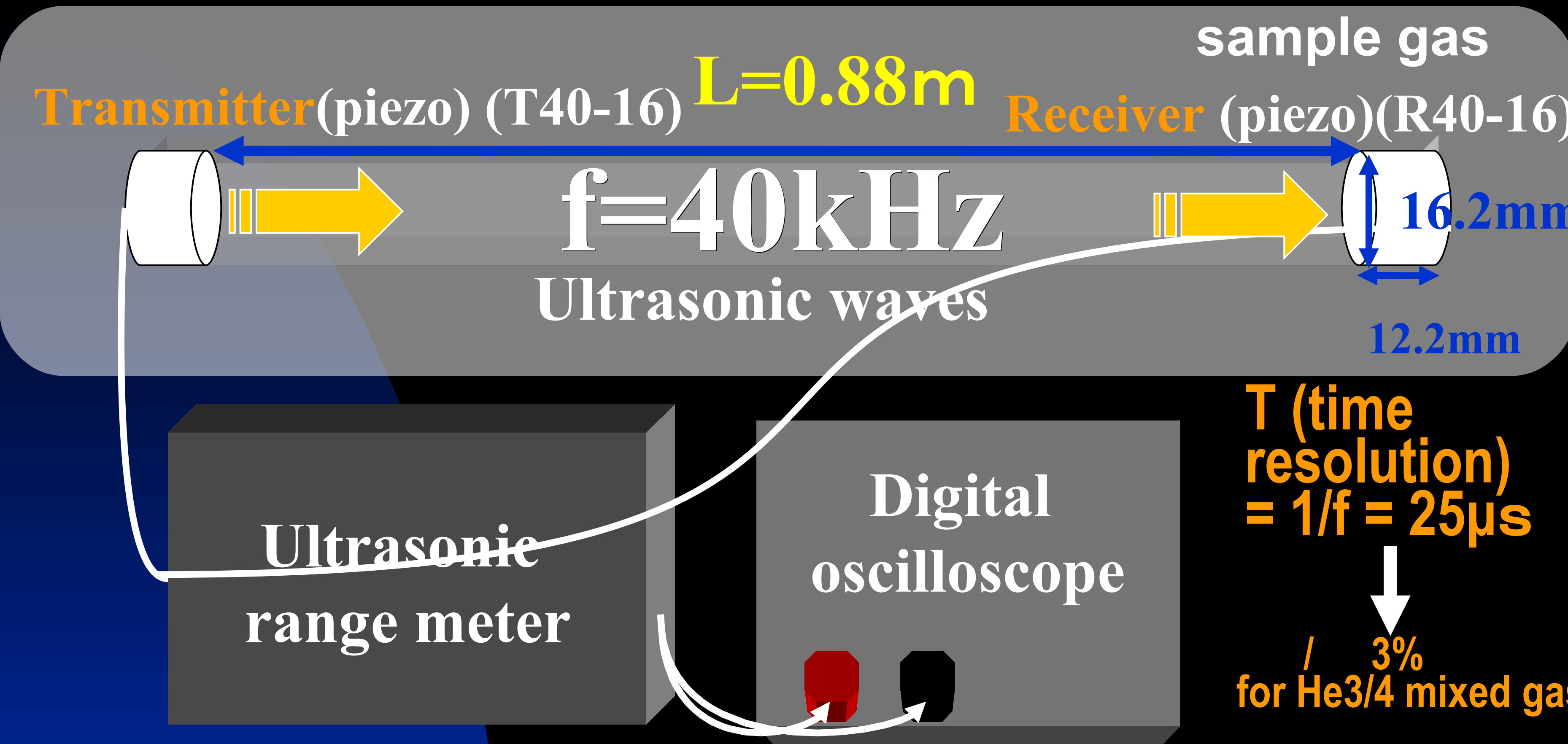


^{4}He fraction(%)

Variation of sound velocity

→**Variation of He3/4 ratio**

Device of measurement



T (time resolution) = 1/f = 25μs

/ 3%
for He3/4 mixed gas

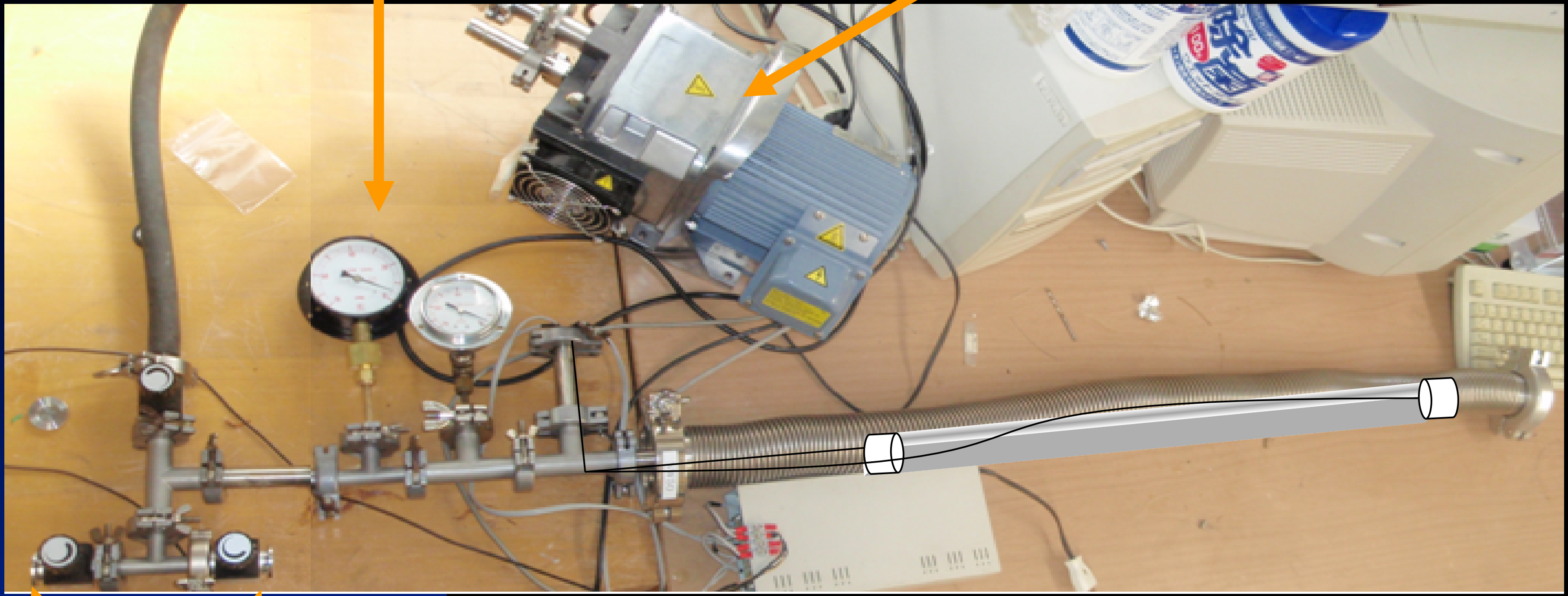
(Error of fraction is 20%)

We observe time difference between transmitter signal and receiver signal

Device of measurement

Bourdon gauge tube barometer

Vacuum pump



N_2.O_2.^4He.^3He.Ar
gas entrance

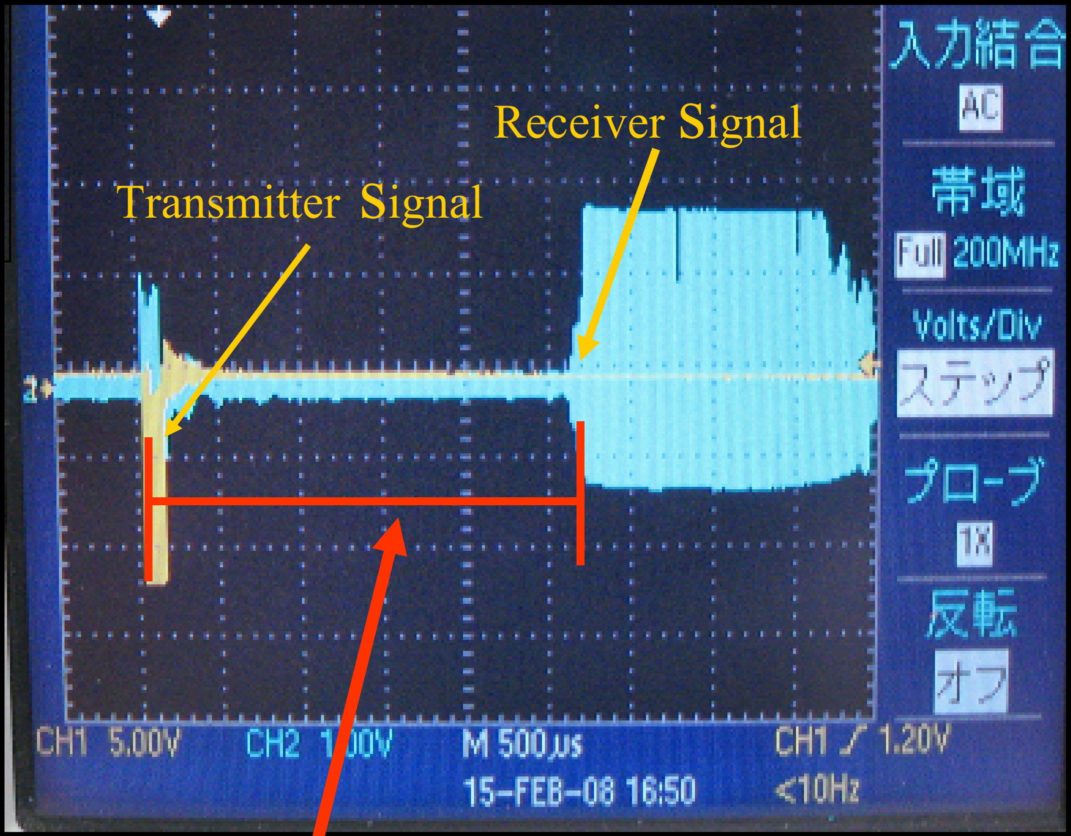
Ultrasonic range meter
(Japan Elekit A type kit)

Principle of measurement

Experiment condition

Fixed Temperature

T 22



Variation of sound velocity gives variation of **τ´**

In this experiment We measure variation of **τ´**

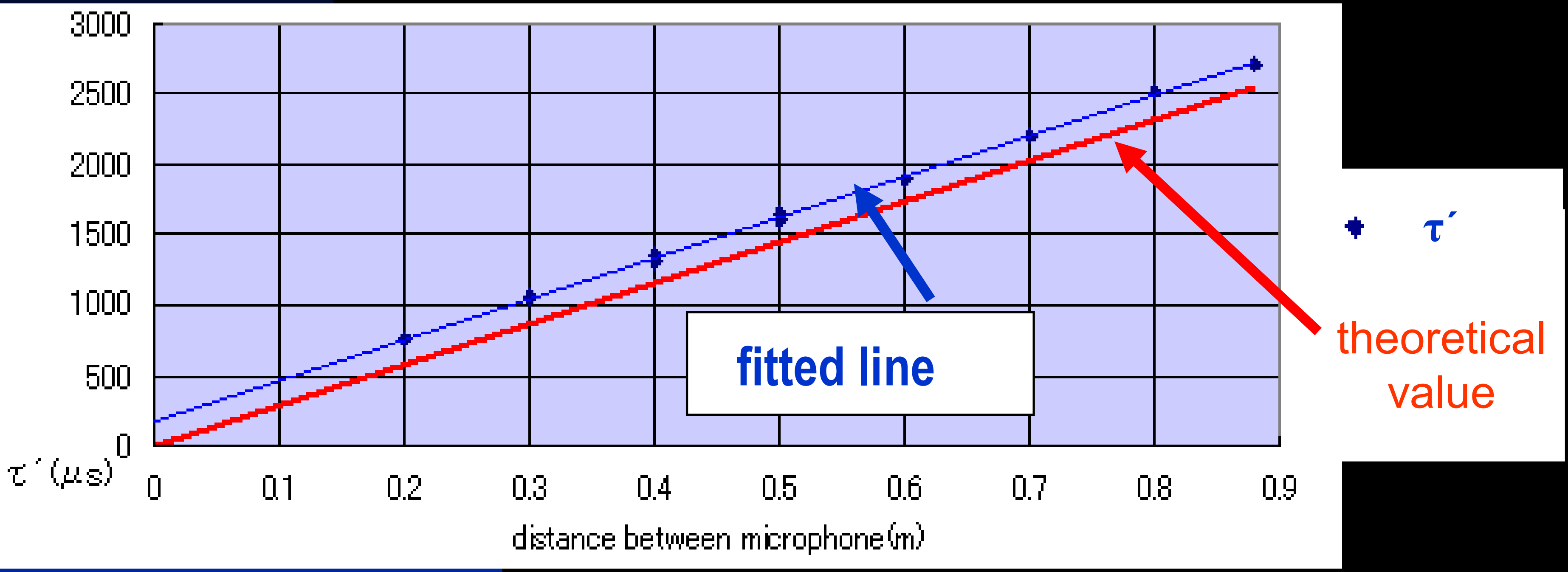
τ´(measured value of time difference between the two signals ）

Sound velocity of air at atmospheric pressure

Examine performance of the device

τ´(measured value of time difference) as a function of distance of propagation

Sound velocity data used as theoretical value : 345.59m/s
temperature 22   humidity 40% (laboratory's condition)



difference between measured value and theoretical value

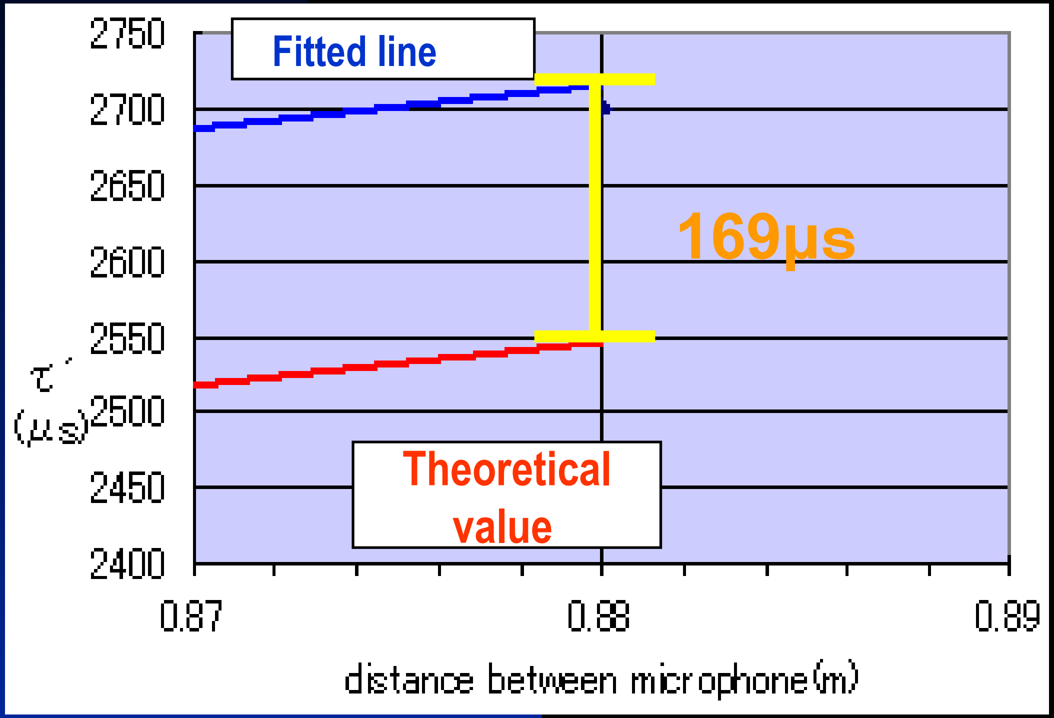
It is considered to be circuit's offset

Determination of τ_0 (offset value)

Comparison of fitting value and theoretical value

theoretical value (0.88m)
T= 2546 (μs)

fitting value of the data points(0.88m)
T=2715(μs)



0.88m(length which is actually use for measure He3/4 ratio)

difference 169μs

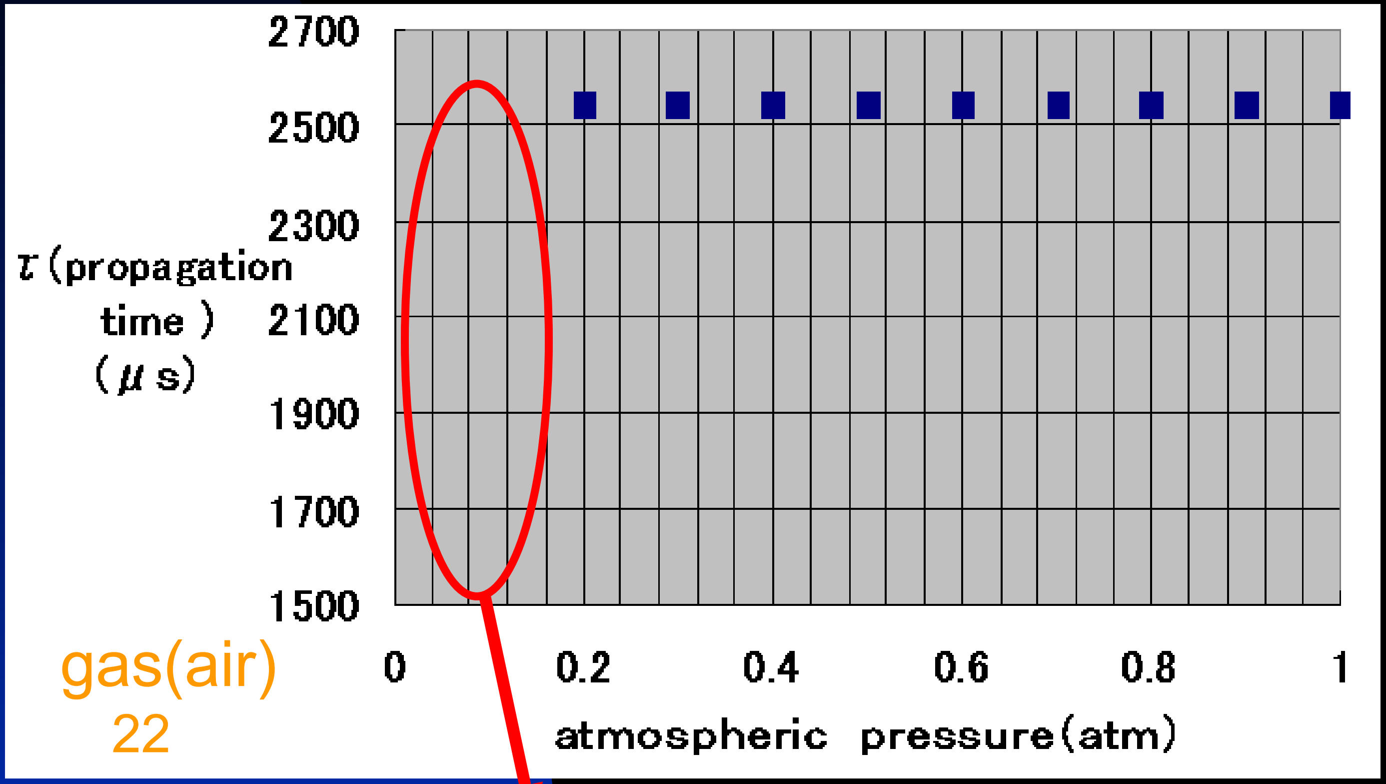
τ_0 is determined to be 169μs

τ(propagation time)=τ'(measured time)− τ_0 (169μs)

From now, τ is compared with theoretical value

Pressure dependence

τ(propagation time) as a function of gas pressure



This data shows sound velocity does not depend on pressure

Lower pressure ,smaller receiver signal.
Signals could not be observed below 0.2 atm

Sample gases

O_2 gas

M = 32

γ = 7/5

V = 327(m/s)

Ar gas

M = 40

γ = 5/3

V= 320(m/s)

N_2 gas

M = 28

γ = 7/5

V = 350(m/s)

^{4}He gas

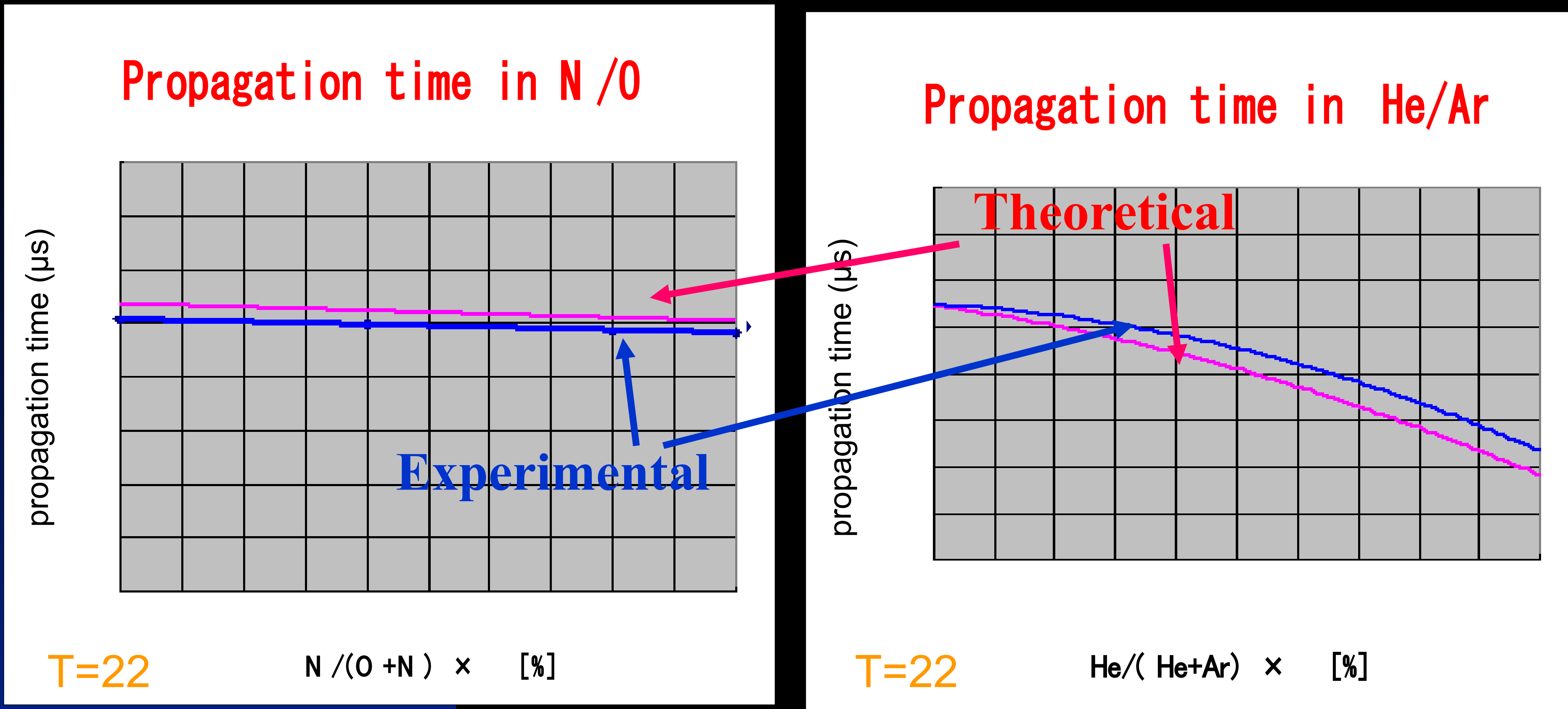
M = 4

γ = 5/3

V = 1011(m/s)

Sound velocity data (T=22)

Measurement results

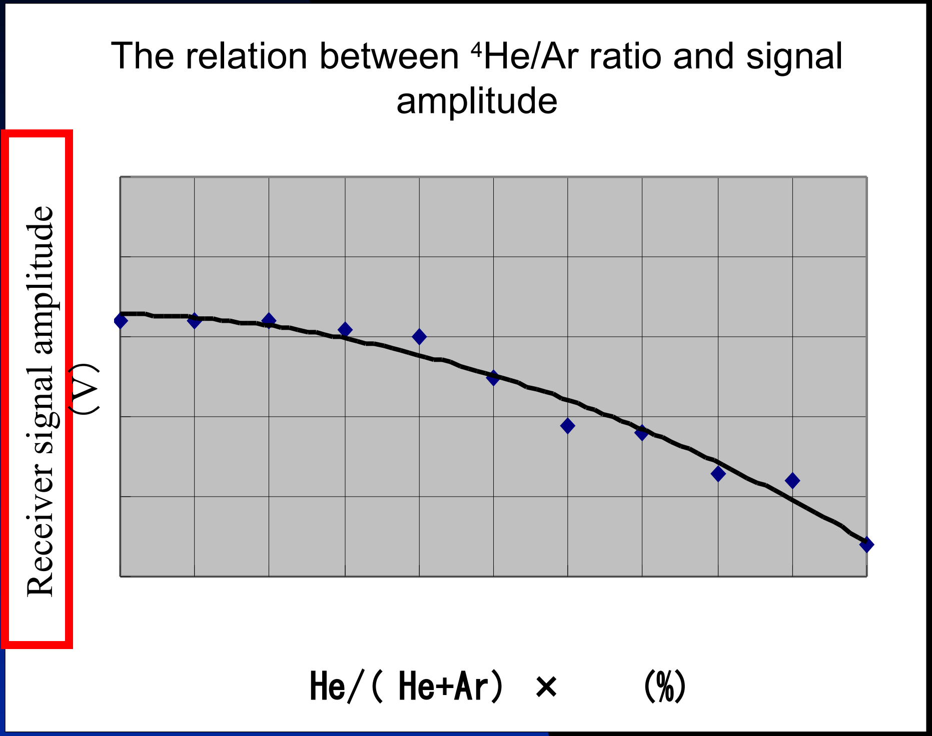


Difference between theoretical and experimental values still remains.

However,we can determine ratio of mixed gas by using calibration with measured values.

Problems of signal amplitude

> $^{4}He/Ar$ ratio measurement is possible.

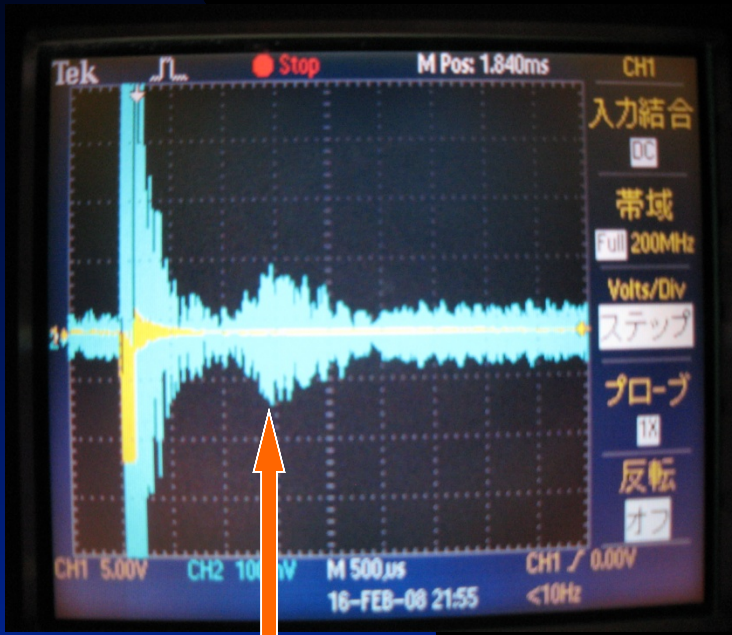


> But！ As ^{4}He fraction increases, receiver signal becomes small.

> For pure ^{4}He gas, signal is quite small！

Problems of signal amplitude

> ^{4}He/Ar ratio measurement is possible.



signal !?

> But ! As ^{4}He fraction increases, receiver signal becomes small.

> For pure ^{4}He gas, signal is quite small !

It is considered that decrease of signal amplitude is due to decrease of average molecular weight

Problems of signal amplitude

Ultrasonic energy E(J/m^3) is

$$E = 2\pi^2 A^2 f^2 \rho$$

（A：amplitude of sound（m） f：frequency of vibration(Hz)

ρ：density of gas(kg/m^3))

>ρ_{He} 1/7ρ_{air} sufficient energy is not obtained compared with in air .

>The same for ^{3}He gas.

>Velocity measurement is difficult for He 3/4 gas with this device.

Summary

- We constructed a gas ratio measurement system.
- The contents and the fractions of the mixed gas were examined by using this device.
- However, He gas molecular weight is small. So the receiver signal becomes small.
- Now we have problems of measurement for He ¾ ratio. **But we found good potential of measurement !**

Outlook

Increasing ultrasonic energy E is important

$$E = 2\pi^2 A^2 f^2 \rho$$

It is the most efficient to raise the frequency

→ **Ideal** **f = 170kHz (Transmitter)**

In addition to time resolution μs

→ **/ 0.7% for He3/4 mixed gas (Error of fraction is 5%)**

Other ways are

- **Making distance of propagation longer**
- **Raising gas pressure**

He ¾ Signal will be improved just like air

Thank you for Listening