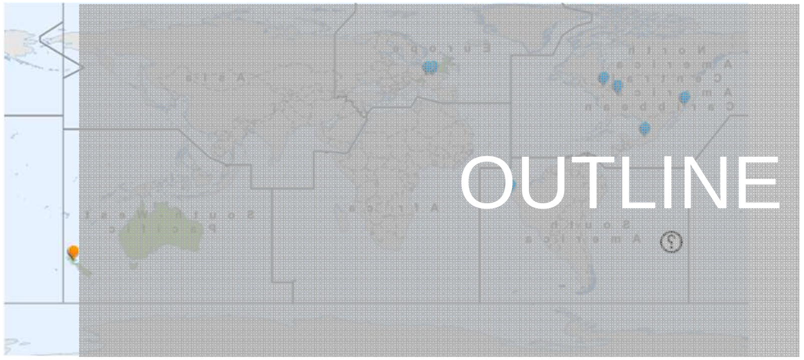
FLOMEKO2019

Design of a Calibration System for Miniature Carbon Dioxide Sensors

Mengna Li, Heming Hu
National Institute of Metrology, China

中国计量科学研究院
National Institute of Metrology,China



01 **Background**

02 **Sensor Overview and Method**

03 **Result and Analysis**

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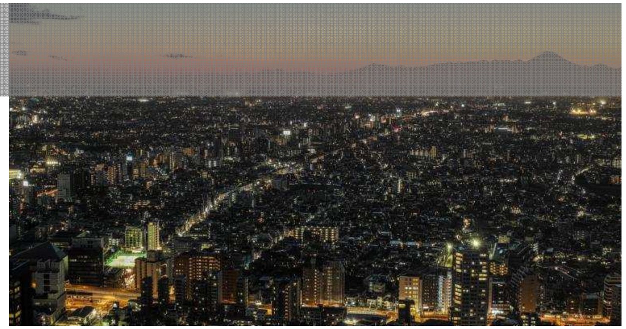
Background



IG3IS

- **Target**

Aiming to provide the most advanced and timely emission system

Asia (Region II)

- **Objective #3**

Beijing-Tianjin-Hebei City Cluster Carbon Monitoring Project

Sub-project

- High-density Observation Network of Miniature Carbon Dioxide Sensors

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Background

Quantifying CO_2 emission

- Multi-point observation method using fixed stations or vehicles.
- Low-cost but accurate sensor is preferable.

Miniature NDIR sensors

- Small, lightweight and inexpensive.
- The accuracy is affected by facotrs such as pressure, temperature and length of use.

Objective

- to explore the principle of NDIR sensors.
- develop a feasible calibration method to improve the precison and accuracy of miniature CO_2 sensors.

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Sensor overview

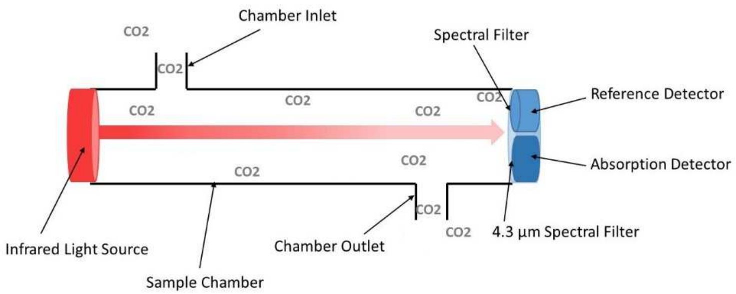
Operating principle

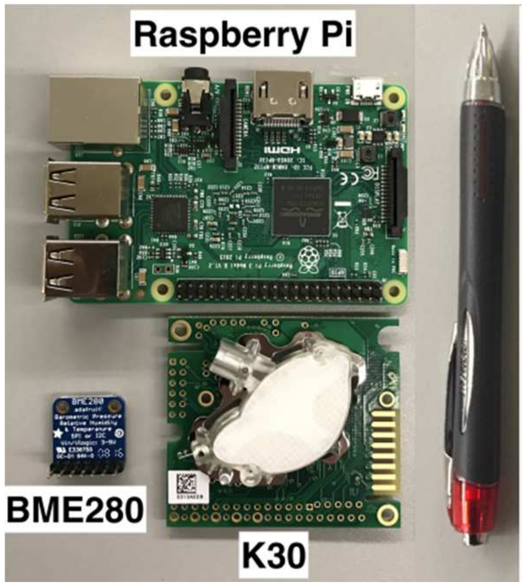
There are two phases in the cycle:

IR_Low -> the IR source is off, background

IR_High -> the IR source is on, attenuation

IR_Signal = IR_High - IR_Low





A SenseAir CO_2 sensor

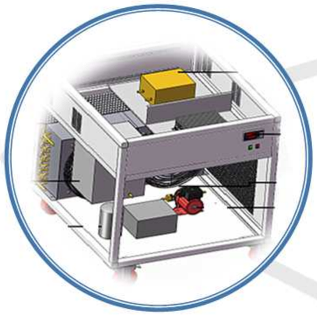
Range 0 - 5000 ppm

Accuracy 30ppm, 3%

Measure of concentration

Method

Apparatus and Connections

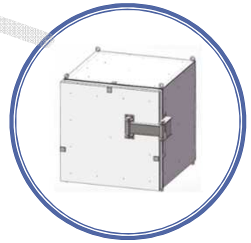


Connections

external vents, pump and drying chamber.

BME280 sensor

providing measurement of the pressure and temperature



Thermostat

K30 sensor and BME sensor are placed in it

Picarro G2311-f analyzer

providing high-precision CO_2 concentration value

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Transmission calculation model

The Beer-Lambert Law

$I = I_0 \, e^{-c\sigma L}$ $\qquad \tau = I / I_0$

$$\tau = \frac{1}{\Delta\upsilon} \exp\left(-\sum_i S_i\,(T)\varphi_i(T,P,\upsilon\,)\frac{PXN_A}{RT}L \right) d\upsilon$$

Spectral line strength

$$S = S(T_s)\frac{Q_V(T_s)Q_r(T_s)}{Q_V(T)Q_r(T)} \exp\left[\frac{1.439E''(T-T_s)}{TT_s}\right]$$

$$Q_V(T) = 1.05385 - 8.11142\times 10^{-4}T + 3.18772\times 10^{-6}T^2$$

$$Q_r(T) = Q_r(T_s)(\frac{T}{T_s})$$

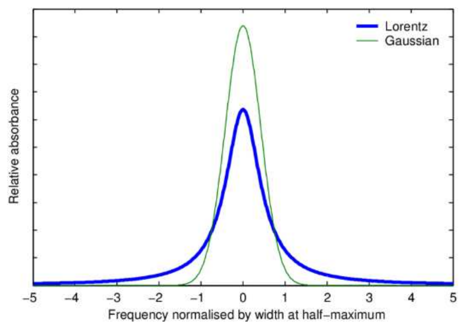
HITRAN2016 Dataset

	Parameter	Units	C | Fortran Format	Err	Ref
ℹ	Molecule ID		I2		
ℹ	Isotopologue ID		I1		
ℹ	ν	cm^{-1}	F12.6	✔	✔
ℹ	S	$cm^{-1}/(molec \cdot cm^{-2})$	E10.3	✔	✔
ℹ	A	s^{-1}	E10.3		
ℹ	γ_{air}	$cm^{-1} \cdot atm^{-1}$	F5.4	✔	✔
ℹ	γ_{self}	$cm^{-1} \cdot atm^{-1}$	F5.3	✔	✔
ℹ	E''	cm^{-1}	F10.4		
ℹ	n_{air}		F4.2	✔	✔
ℹ	δ_{air}	$cm^{-1} \cdot atm^{-1}$	F8.6	✔	✔

The linear function

Lorentz distribution

$$\varphi(T,P,\upsilon) = \frac{\alpha_L}{\pi[(\upsilon-\upsilon_0)^2+\alpha_L^2]}$$



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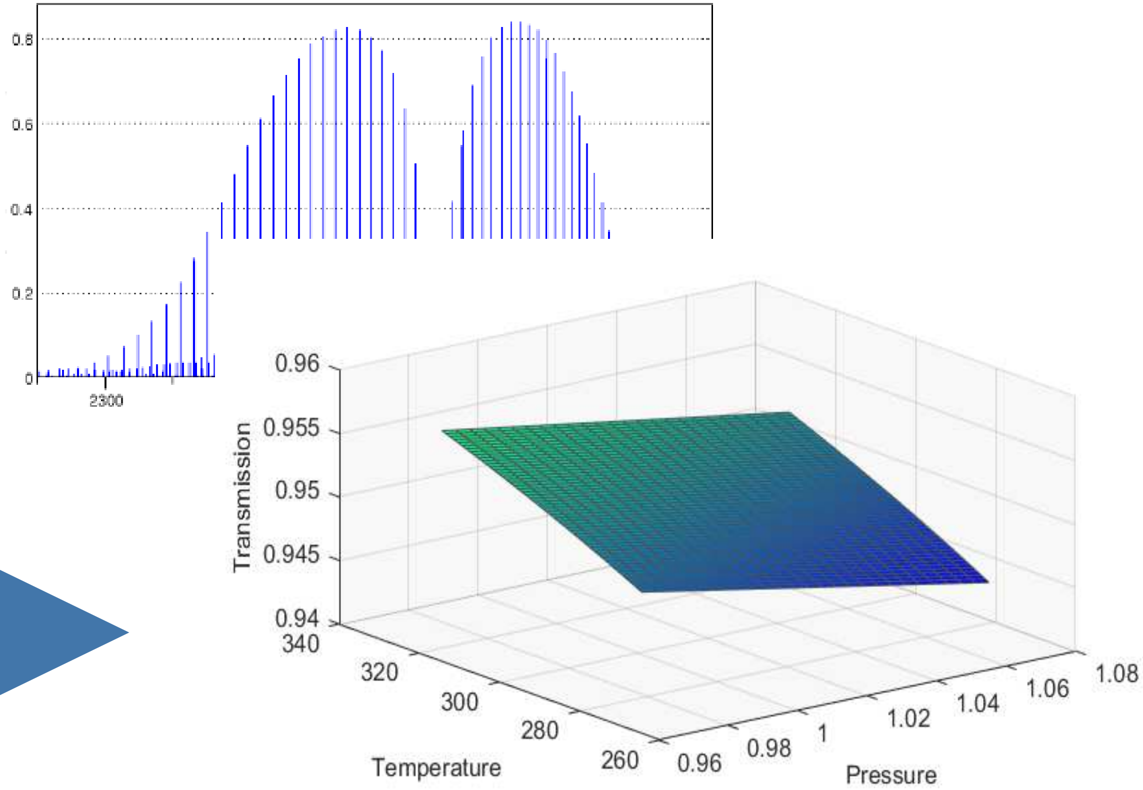
Transmission calculation model



Integration of spectrum

The CO_2 absorption spectral range is 2280-2400 cm-1 .

Modified line strength

Compensate the error caused by truncation, $S' = S/(1 - \frac{2}{\beta\pi})$

Temperature

set between 273 K and 323 K.

Pressure

between 0.96 atm and 1.08 atm.

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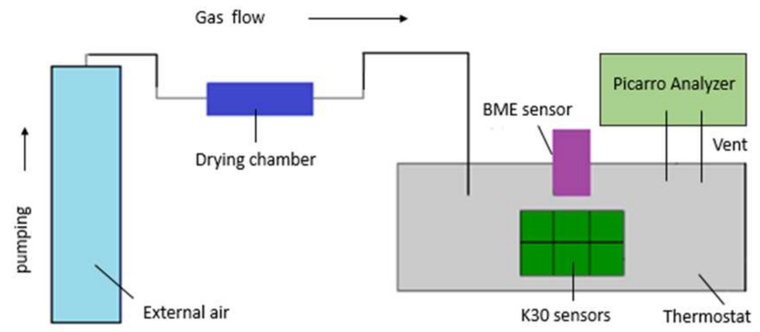
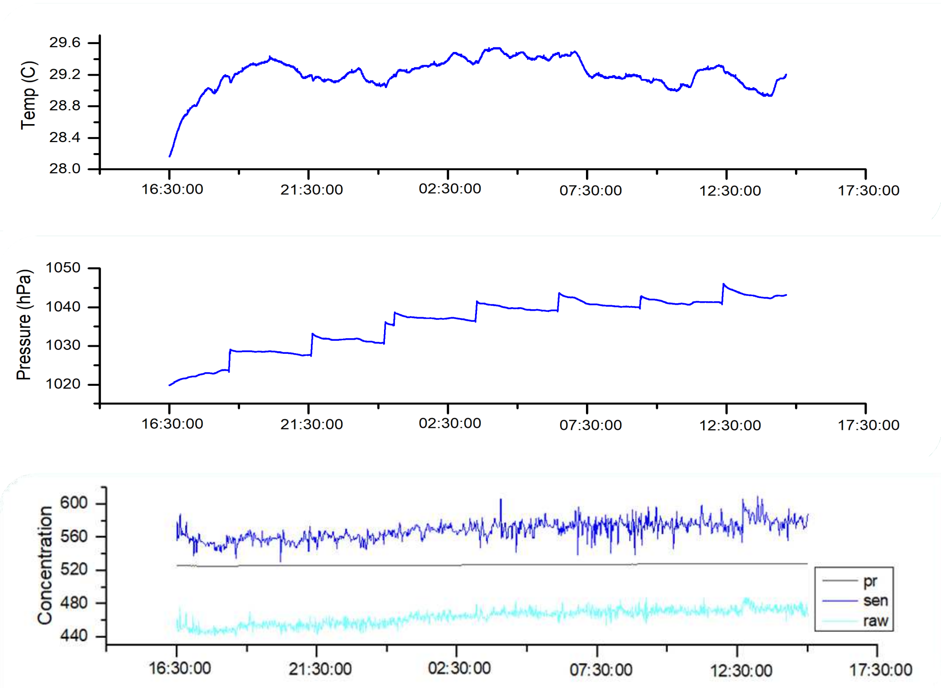
Experimentally observed data





Temperature and pressure by BME

Observed signal by K30 and Picarro analyzer

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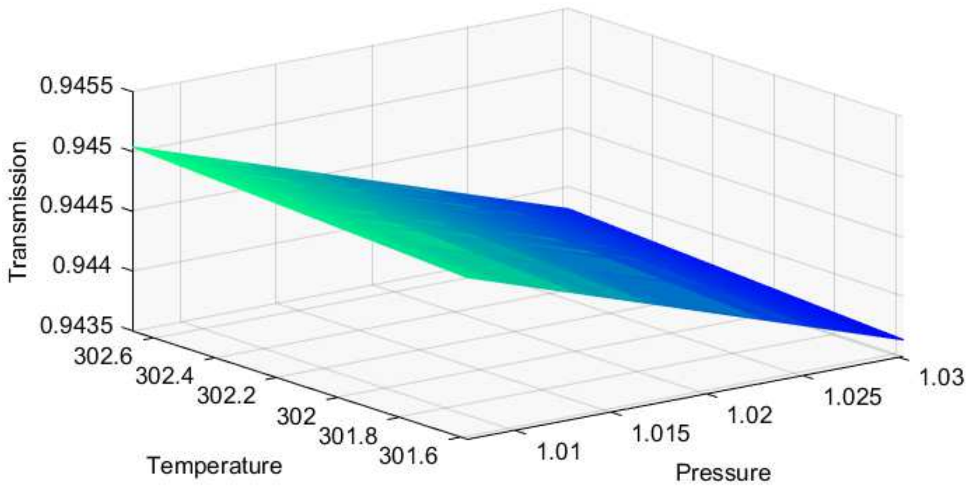
Theoretical transmission calculation



Theoretical Transmission

The non-linear curves of tansmssion as a function of temperature and pressure obtained.

Variables Dependence

The concentration is sufficient to make the CO2 effectively opaque in spectral region at higher pressure.

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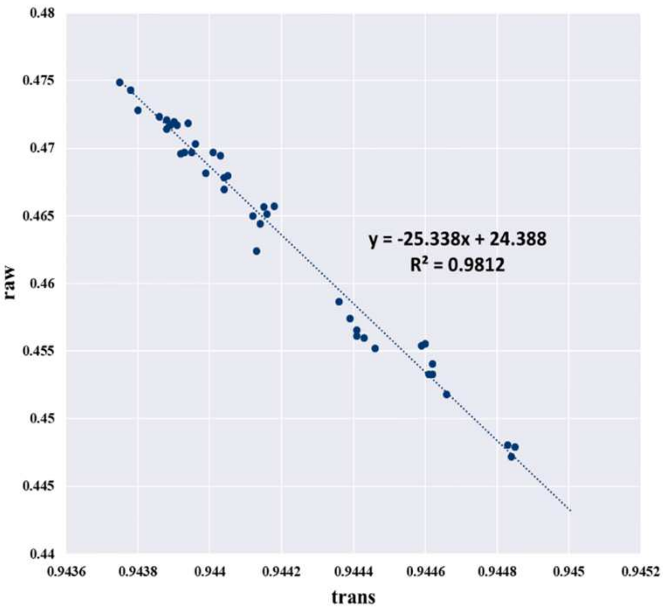
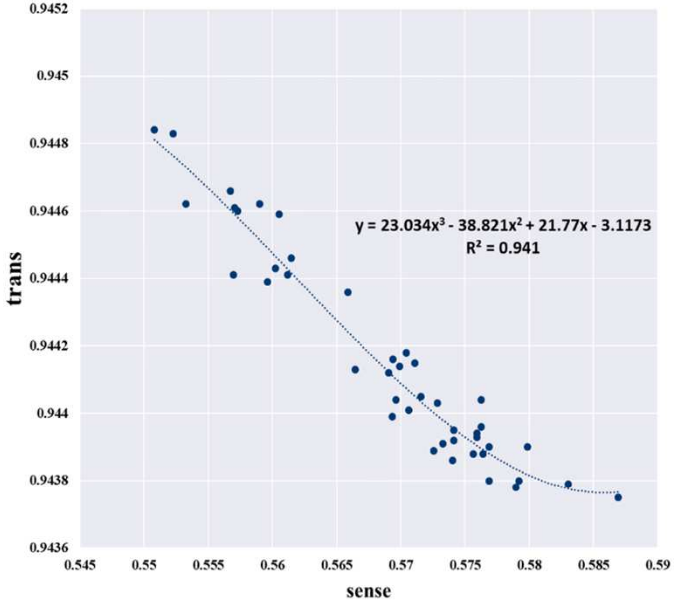
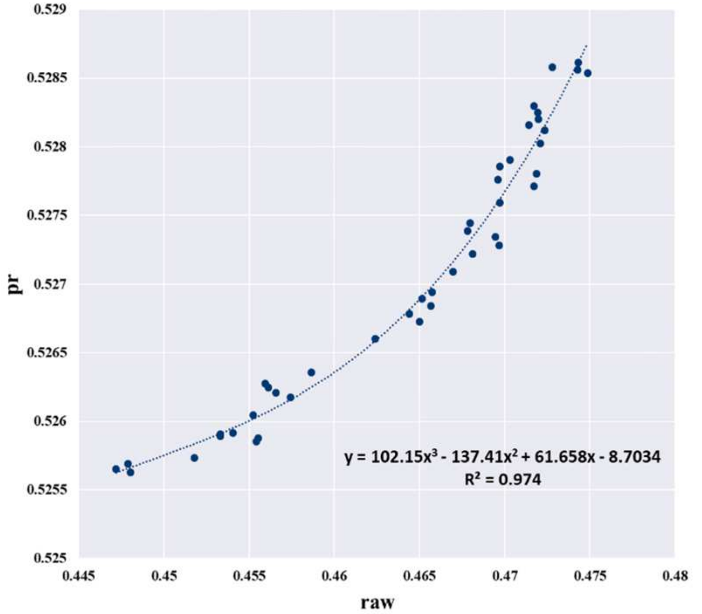
Result and Analysis



Theoretical data and the raw signal of K30



Theoretical data and the observed signal of K30



Measurement of Picarro and raw signal of K30

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Fitting transmission to observed signal

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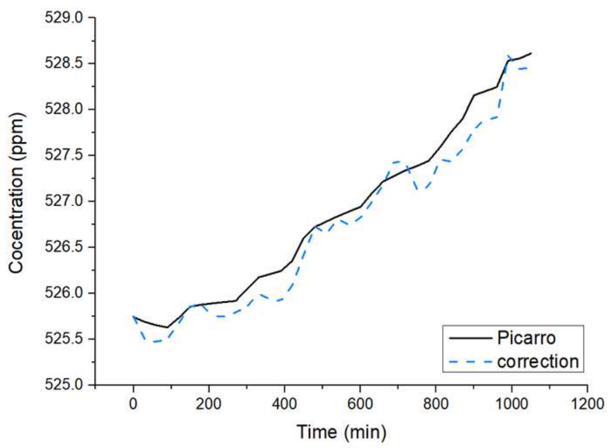
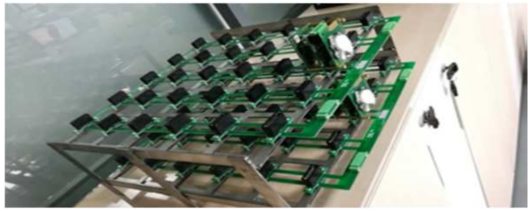
Result and Analysis





The output of the K30 sensor was corrected based on the regression analysis . Comparison between the CO2 concentration measured by Picarro-G2311f and corrected result of K30 sensor is made.

The relative root mean squared error (RRMS) difference of the corrected value is 0.46%. A good agreement between the corrected value of K30 sensor and the measurement of Picarro analyzer.

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Conclusion

01

The principle of minature NDIR sensors is explored. A theoretical transmission model is established.

02

Variables dependence, including temperature and pressure, of the sensor is explored.

03

A calibration method of miniature CO_2 sensors K30 is developed.

Future work

To quantify the interference of H_2O, further experiment can be conducted at a series of fixed H_2O values

THANKS

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limmn@nim.ac.cn

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中国计量科学研究院
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