Ammonia Measurements in Exhaust Using PEMS and SEMS

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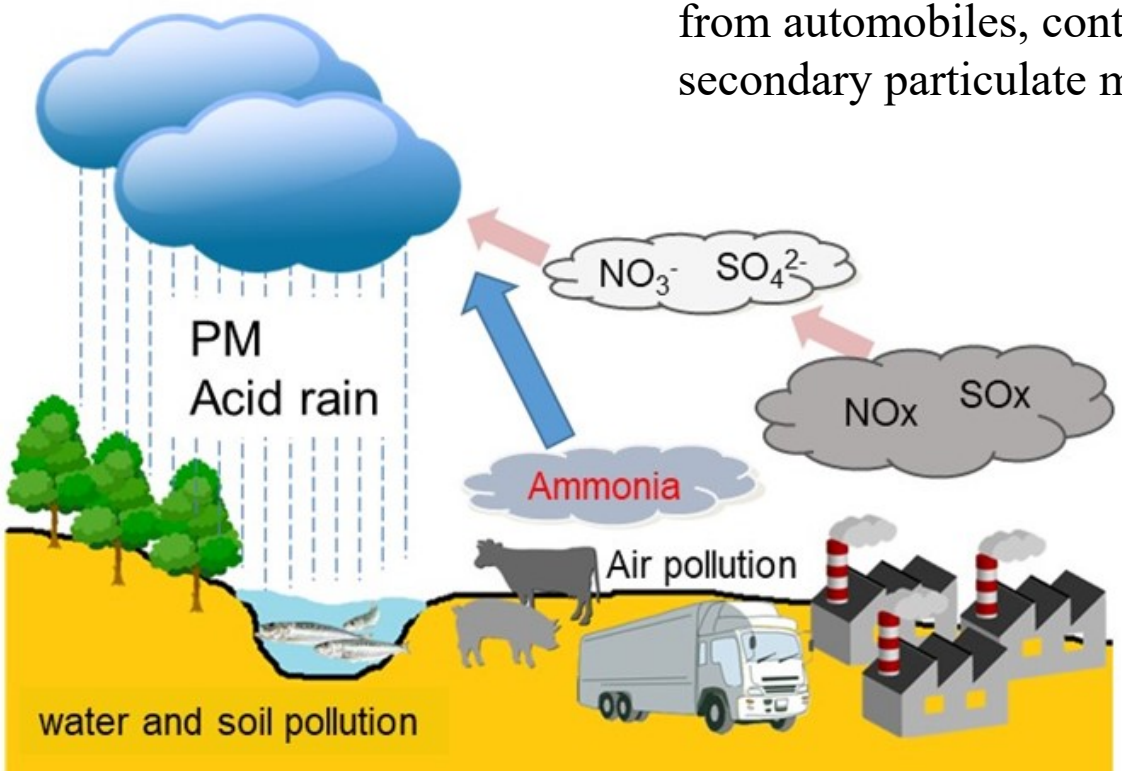
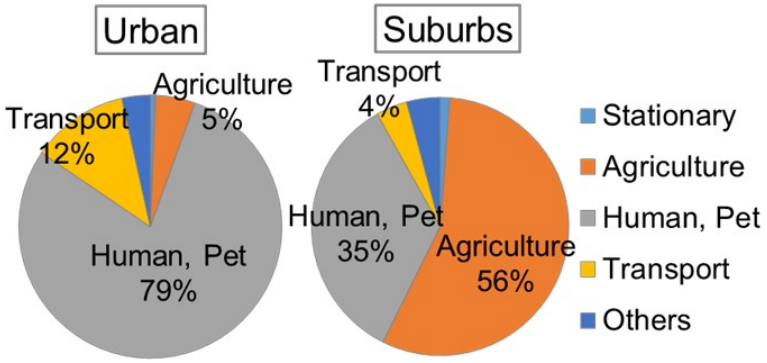
Ammonia (NH_3)

NOx, HC and CO has been reduced due to the improvement of the engine combustion and the use of after-treatment system.

Ammonia (NH_3) is one of the unwanted gas emitted from automobiles, contributing to the production of secondary particulate matter.

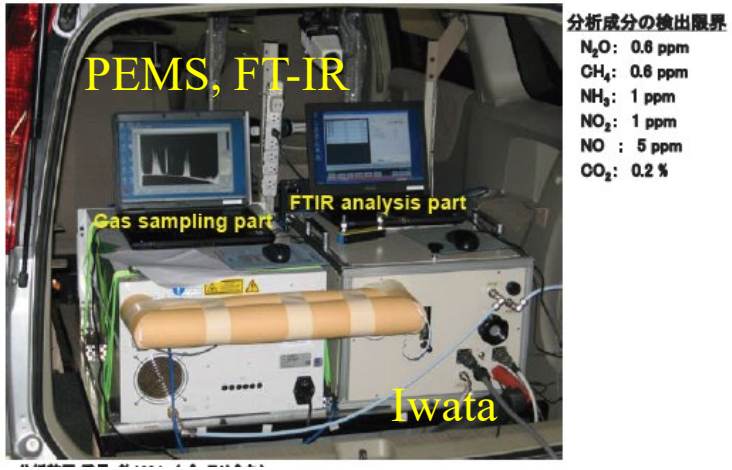


NH_3 emission sources (Kanto area, 2008)



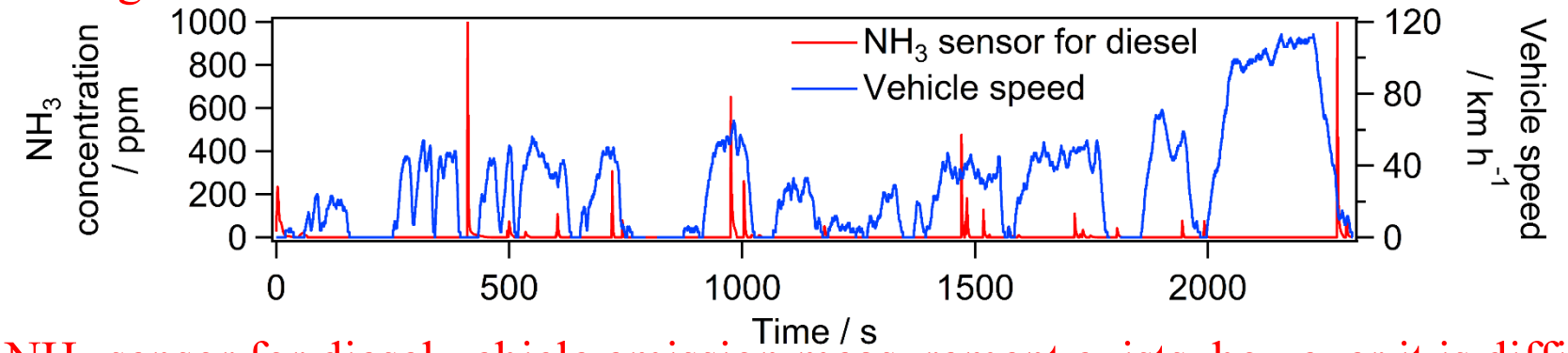
From PEMS to SEMS

PEMS is heavy, which has an influence on emission.



To measure NH_3 emission, FTIR or our developed laser-based measurement system are set in the automobiles. (Total system weight (battery, instrument etc.) is approximately 100 kg)

Sensor-based measurement system (SEMS) is attractive because system is small and light.



NH_3 sensor for diesel vehicle emission measurement exists, however it is difficult to measure NH_3 in gasoline vehicle emission.

Objectives

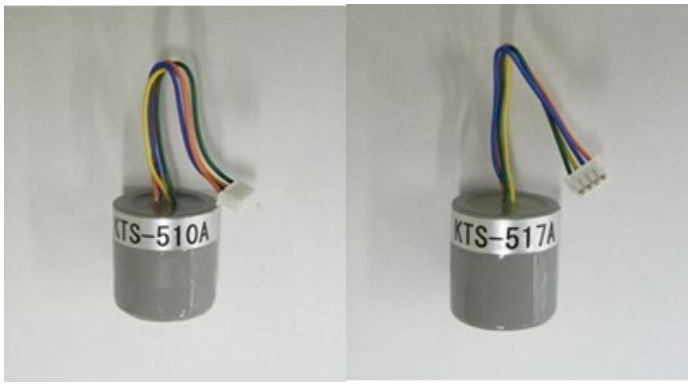
To measure real-world NH_3 emitted from gasoline vehicles using a sensor-based measurement, and to elucidate tendency of NH_3 emission in real world.

- Evaluation of sensor-based measurements of NH_3

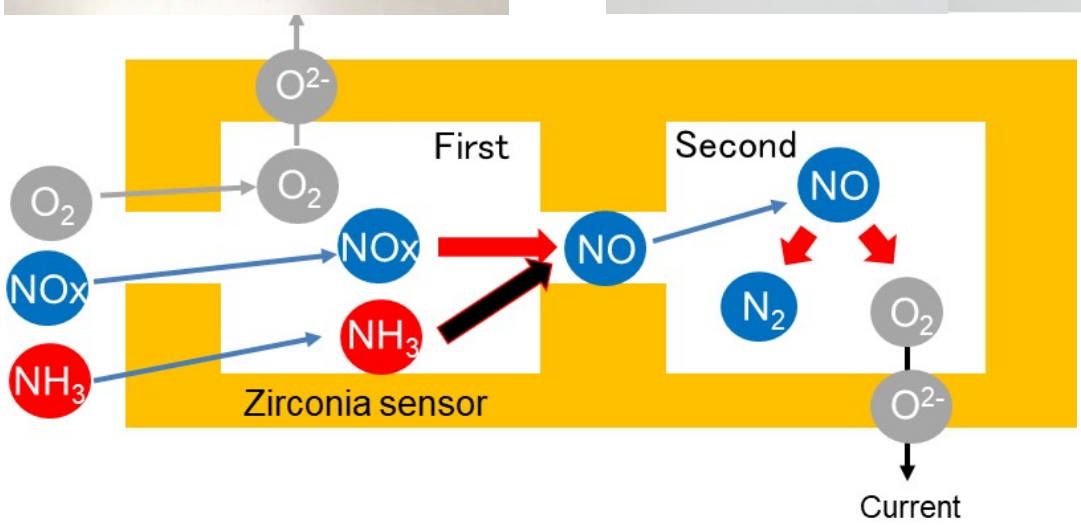
Sensor based measurement system for NH_3

NOx sensor (NCEM)

Potential sensor for NO,NH_3



NH3 sensor for diesel



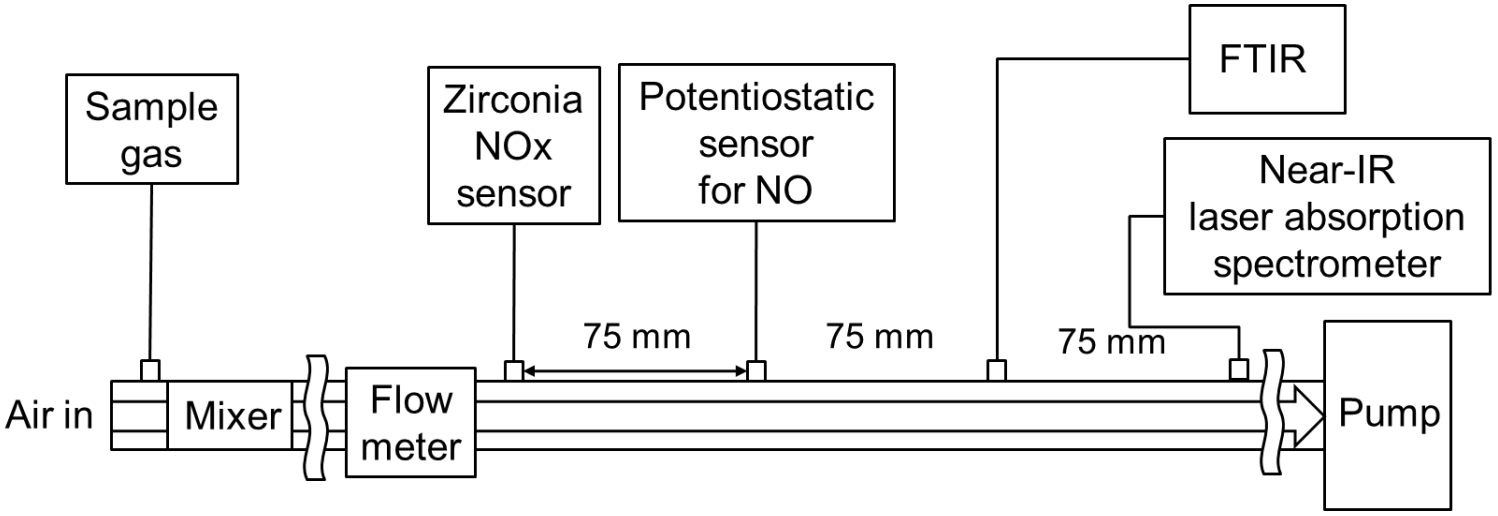
- Signals obtained from NOx sensor include those derived from NO and NH_3.
- Potential sensor for NO can measure the NO concentration.

[NOx sensor] – [Potential sensor for NOx] ≈ NH_3

When NOx sensor and potential sensor for NO are used, ammonia emitted from gasoline vehicles will be measured.

Sensor signals were compared with those obtained by FT-IR and laser-based measurement system.

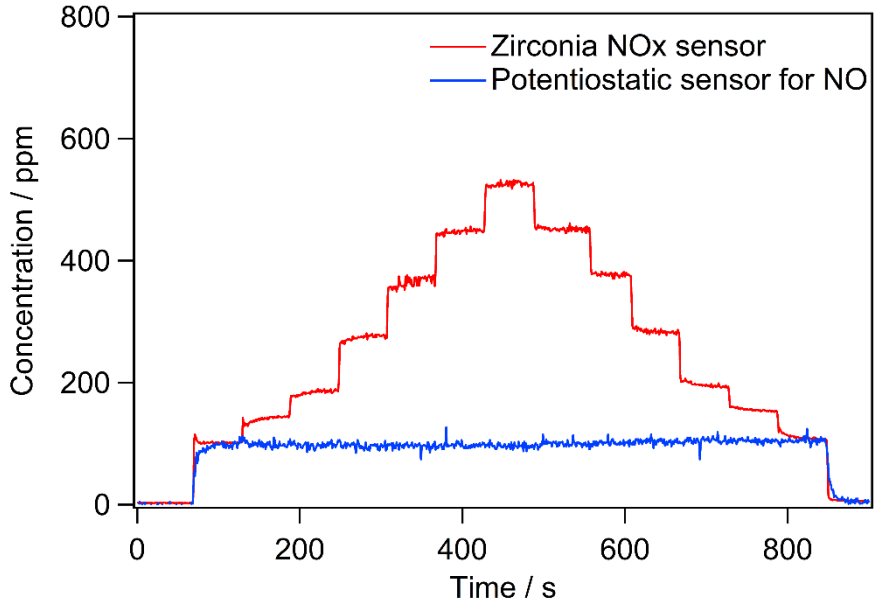
Evaluation of NH_3 signal obtained by each measurement system

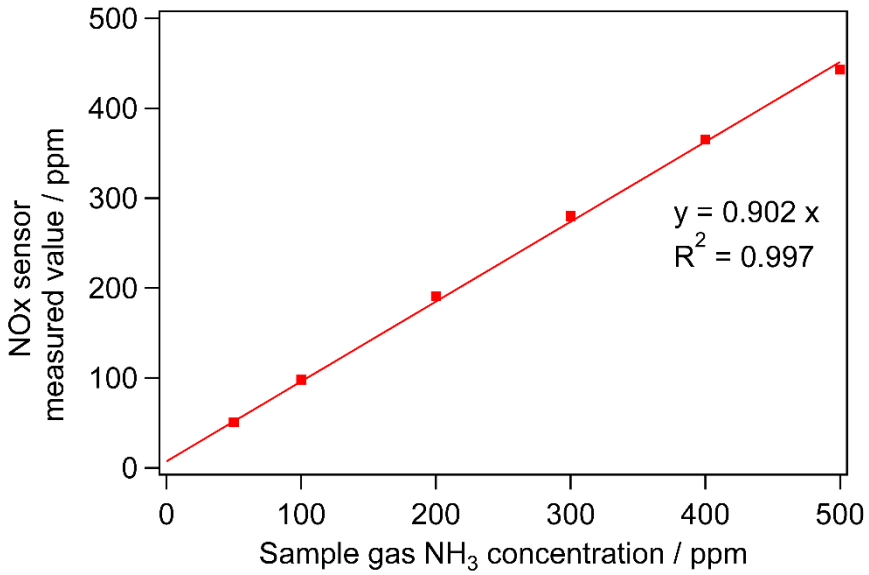


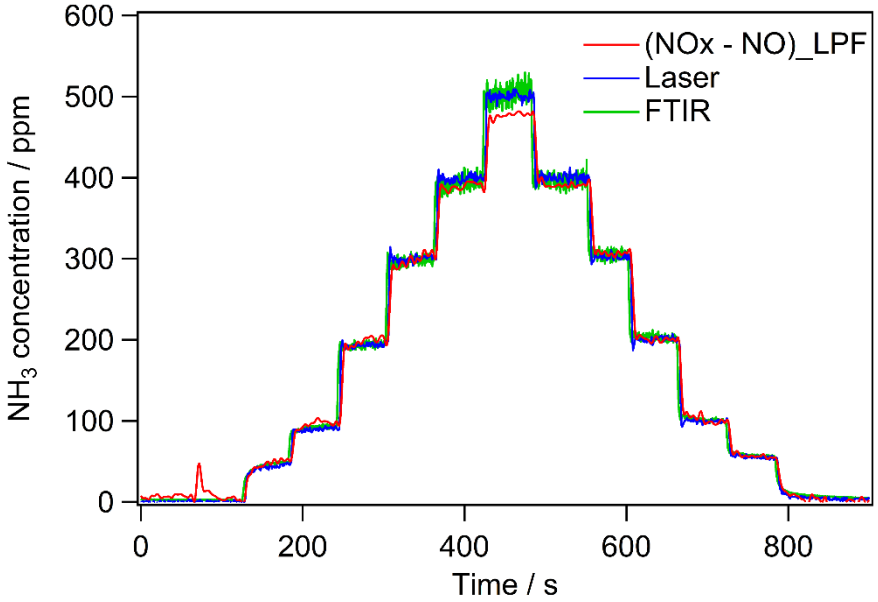
Pressure [atm]	1					
Temperature [K]	298					
Flow rate [L / min]	880					
NO [ppm]	50	100	200	300	400	500
NH_3 [ppm]						
NO+NH_3 [ppm]	50	100	200	300	400	500
NO+NH_3 mixing ratio	1:1, 1:3, 3:1					

- Using NO and NH_3 standard gas, the procedure of NH3 measurement using two sensors was evaluated.
- The obtained NH_3 signal using sensors were compared with those obtained by FTIR and laser-based measurement system.

NH_3 signals obtained by each instrument

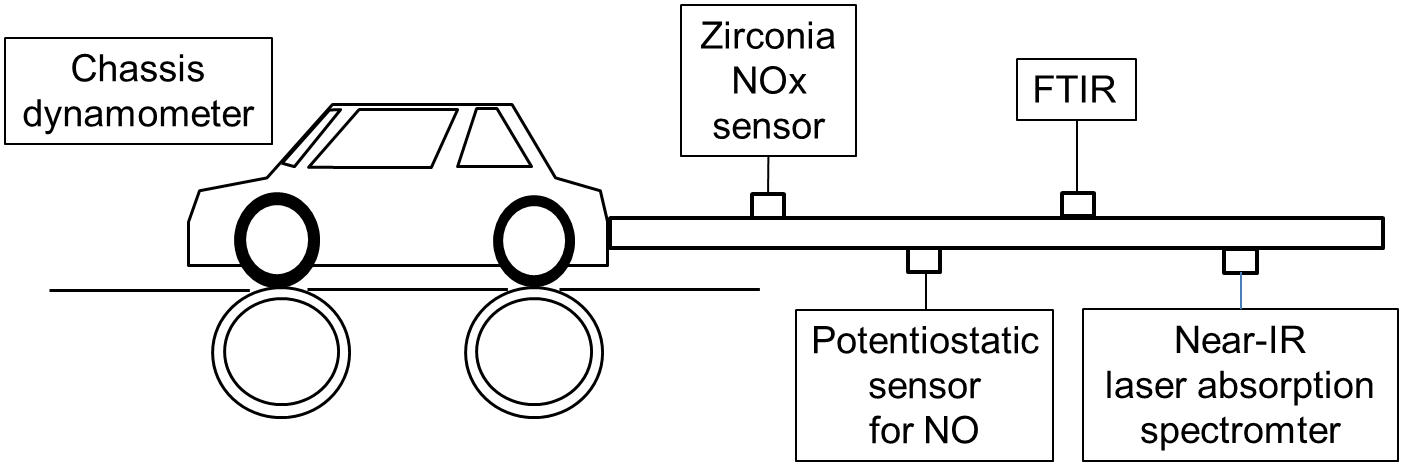






- NOx sensor signals were calibrated by the NH_3 standard gas.
- NH3 concentration obtained by two sensors are in good agreement with those obtained by FTIR, and near-IR laser-based measurement system.

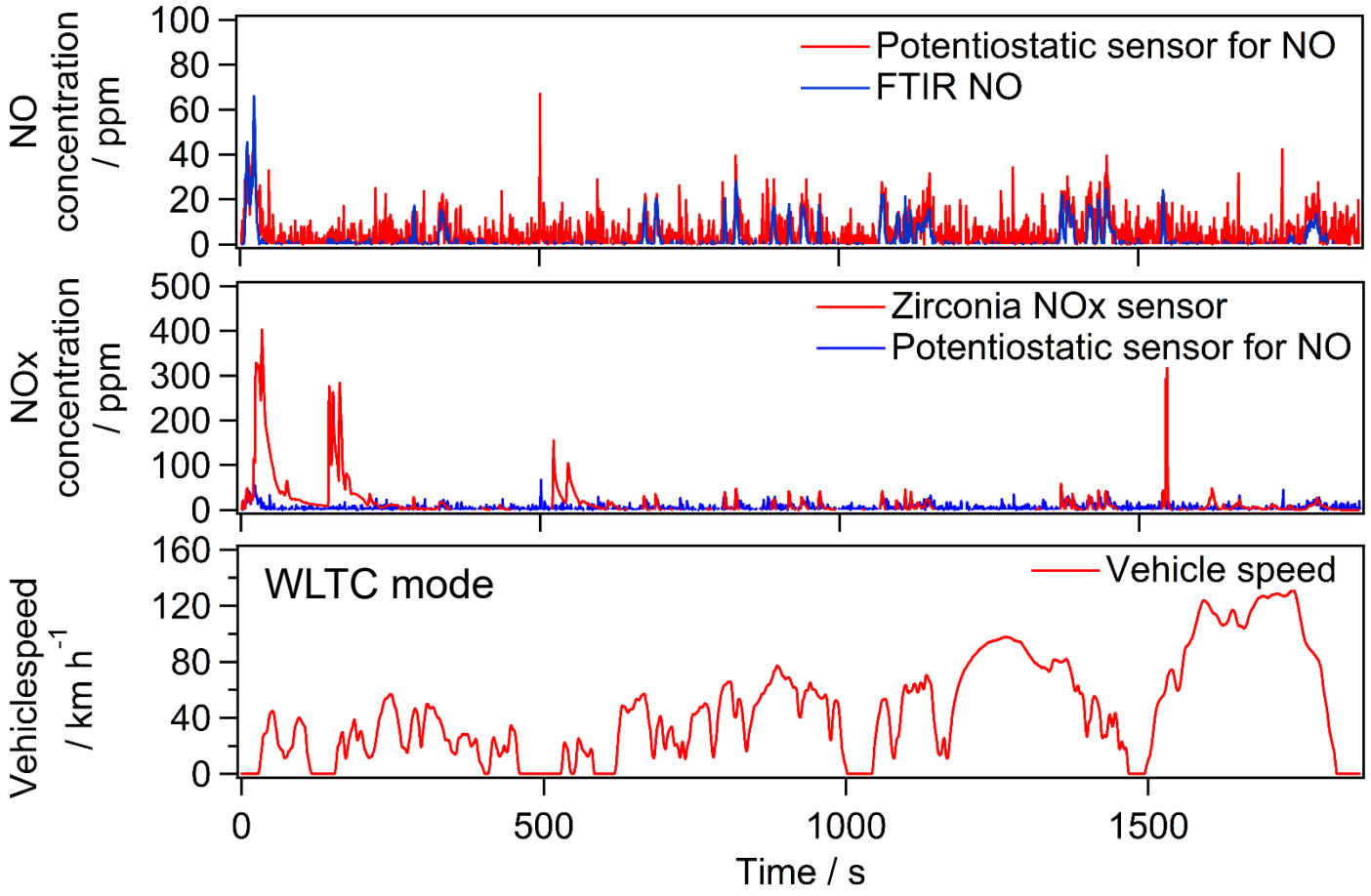
Measurement of NH_3 in gasoline vehicle emission



Car number	NO.1	NO.2
Engine type	In line 4 cylinder NA	In line 4 cylinder turbo
Displacement (cc)	2693	1618
Max. power output (kW per rev / min)	120 / 5200	140 / 5600
After treatment device	TWC	TWC
Vehicle mass (t)	2.475	1.565
Emission standard	2005	2005
Mileage traveled (km)	16145	25218
Model year	2017	2014

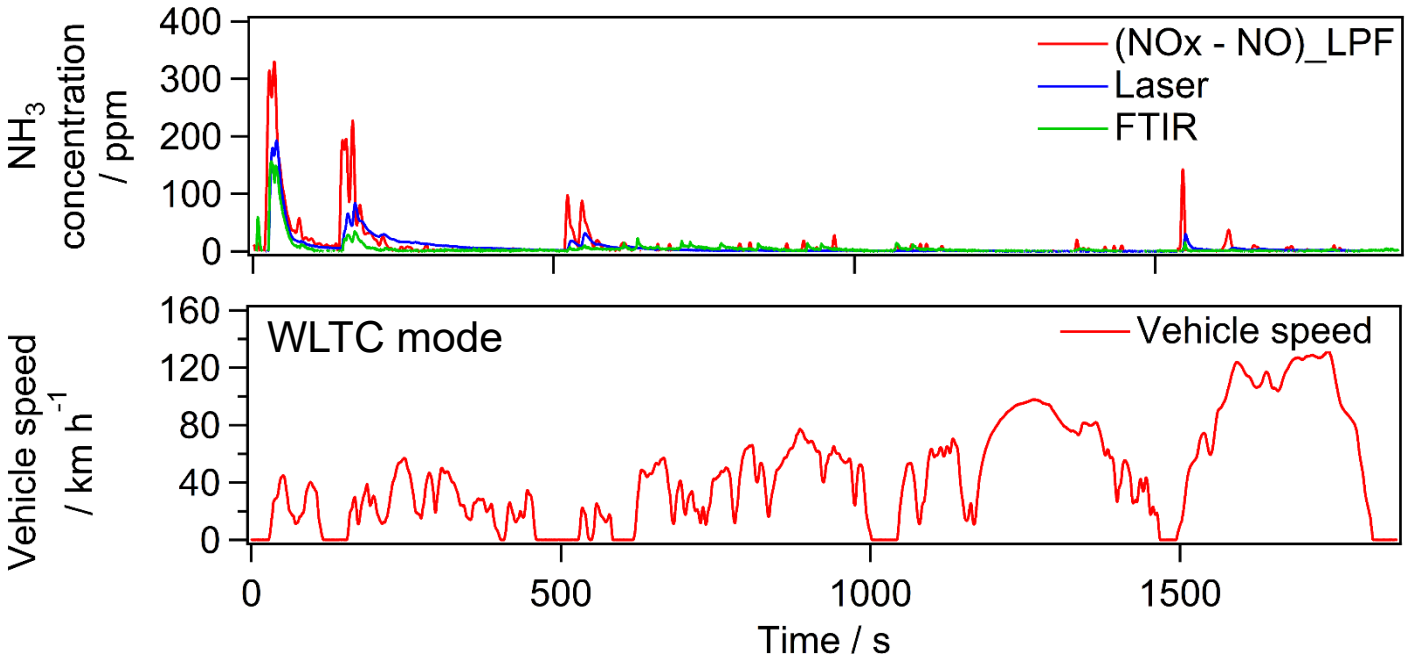
- WLTC mode (cold start)

NOx sensor signals (No.1 vehicle)



- NO concentration obtained by potential sensor for NO was in good agreement with that obtained by FTIR.
- NO concentration obtained by NOx sensor was larger than that obtained by potential sensor for NO.

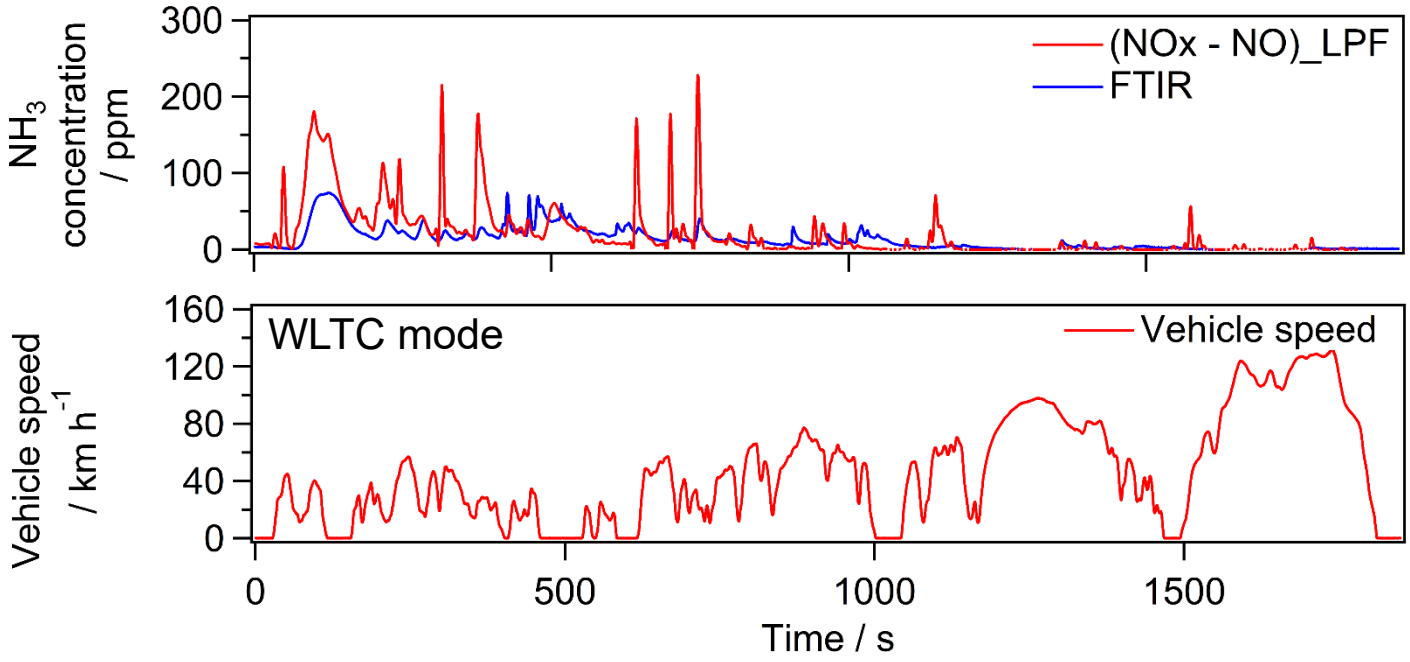
NH_3 in gasoline vehicle (No. 1)



NH_3 emission (mg/km]	
Sensor	17.9
FTIR	8.53
Laser	5.68

- Tendency of NH_3 concentration obtained by two sensors were in agreement with those obtained by FTIR and laser-based measurement system.
- The concentration obtained by two sensors was larger than those obtained by FTIR and laser-based measurement system.
- NH_3 was emitted under the acceleration and engine start conditions .

NH_3 in gasoline vehicle (No. 2)

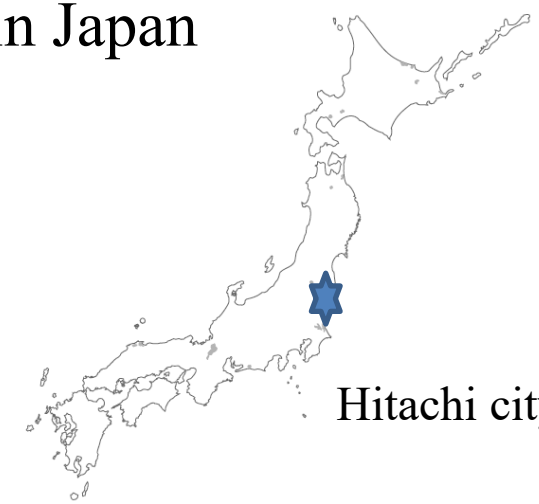


NH_3 emission (mg/km]	
Sensor	6.23
FTIR	3.74

- Tendency of NH_3 concentration obtained by two sensors were in agreement with those obtained by FTIR and laser-based measurement system.
- The concentration obtained by two sensors was larger than those obtained by FTIR and laser-based measurement system.
- NH_3 was emitted under the acceleration and engine start conditions .

Route for emission measurements

Test route was set in Hitachi city in Japan

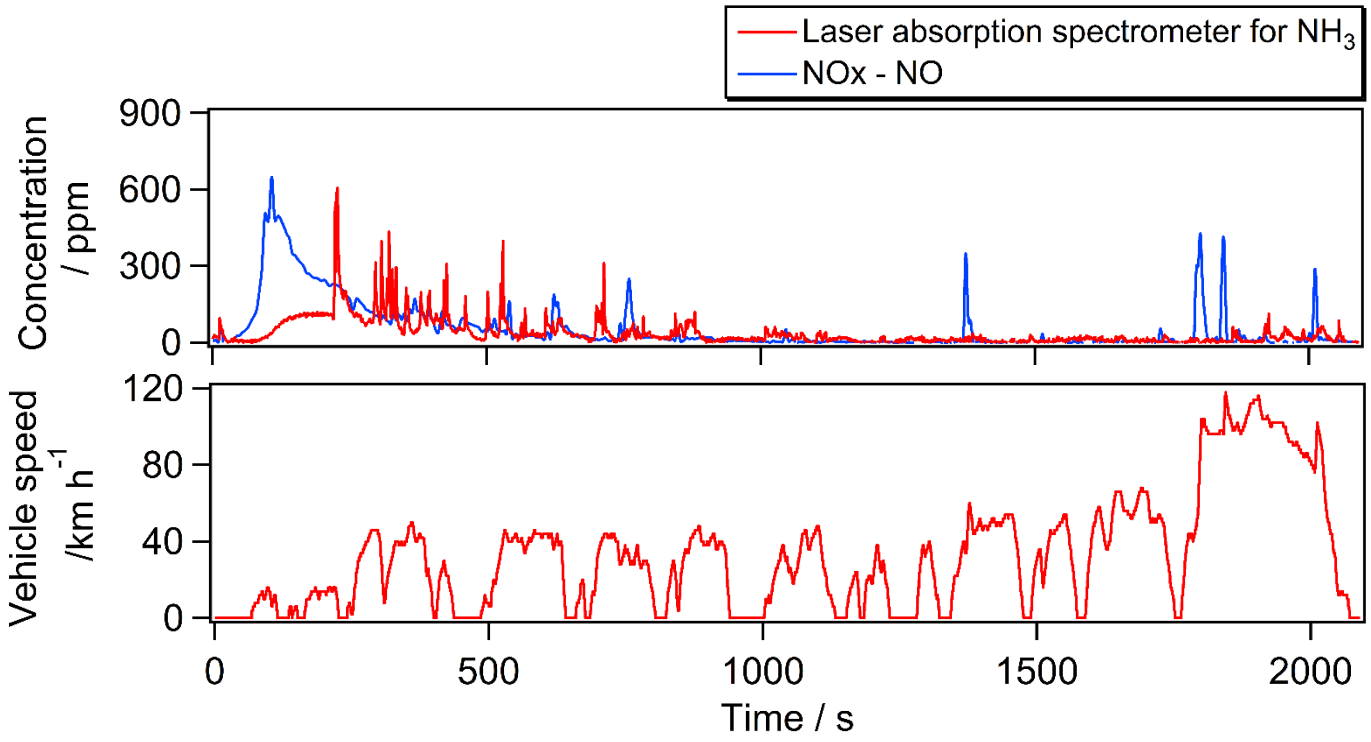


Hitachi city

Test route

Urban (A – B)	5.4 km
Rural (C – A)	6.2 km
Highway (B – C)	7.0 km
Total length	18.6 km
Altitude difference	110 m
Test time	30～40 minutes

RDE measurement of NH_3 in gasoline vehicle (No. 2)



NH_3 emission (mg/km]	
Sensor	47.5
Laser	18.4

- Now, on board measurement of NH_3 in gasoline exhaust is performed.
- There are some difference between the NH_3 concentration obtained by two sensors and that obtained by laser-based measurement system. The cause of the difference are analyzed and NH_3 measurement in gasoline vehicle will be continued.

Summary

- NH_3 measurement procedure using a zirconia NOx sensor and an NO potential sensor was evaluated. It is found that there is possibility that NH_3 emitted from gasoline vehicles can be measured using the two sensors.

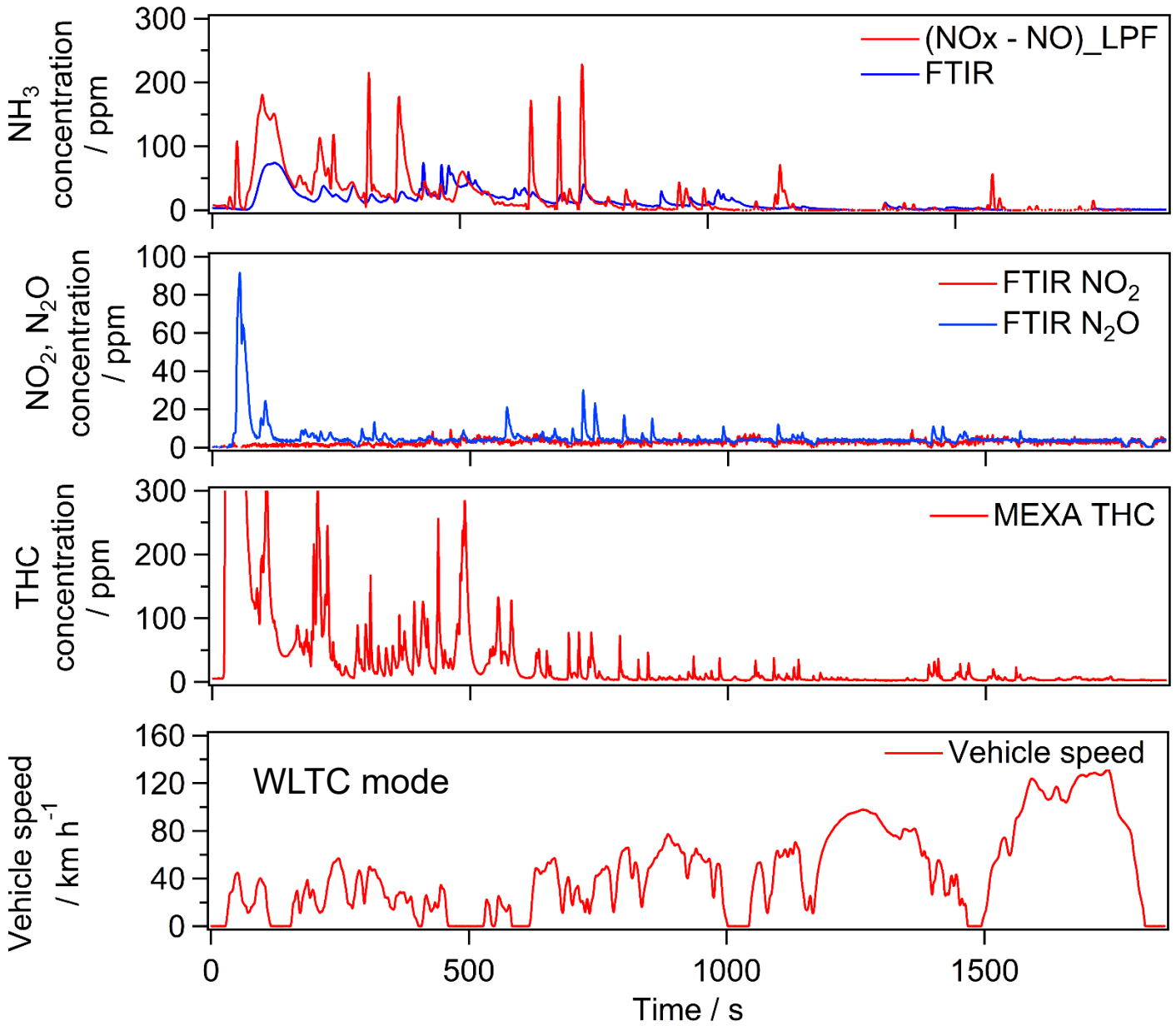
- It is confirmed NH_3 was emitted from gasoline vehicles under the highspeed and acceleration conditions, and the conditions where engine starts.

- There are some difference between the NH_3 concentration obtained by the sensors and that obtained by laser-based measurement systems, whose causes will be analyzed and the measurement of real-world NH_3 emitted from gasoline vehicles will be continued.

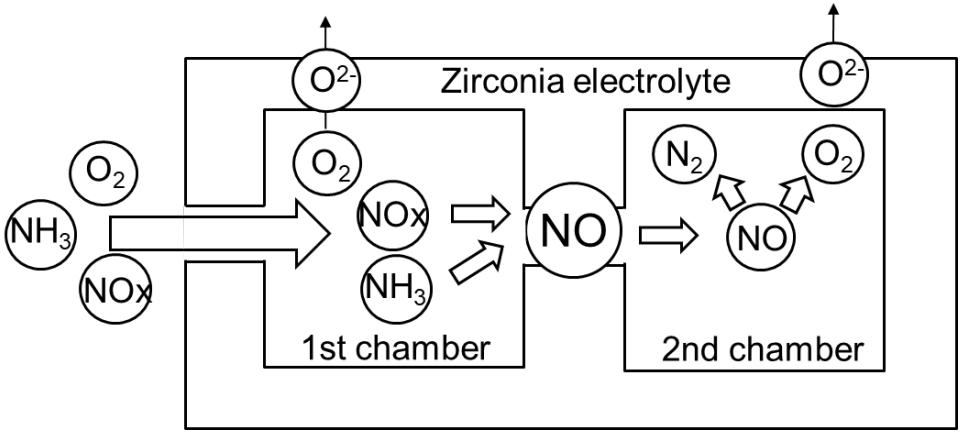
Thank you for your kind attention.

Appendix

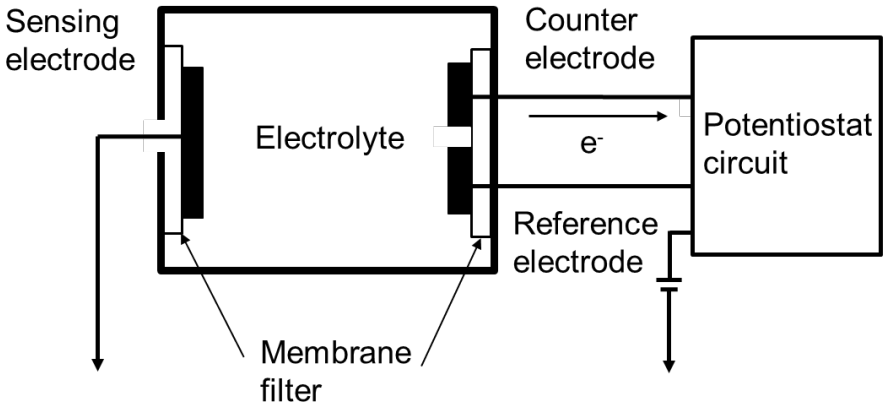
NH_3, NO_2, N_2O, THC signal(No. 2 vehicle)



NOx sensor (NCEM)

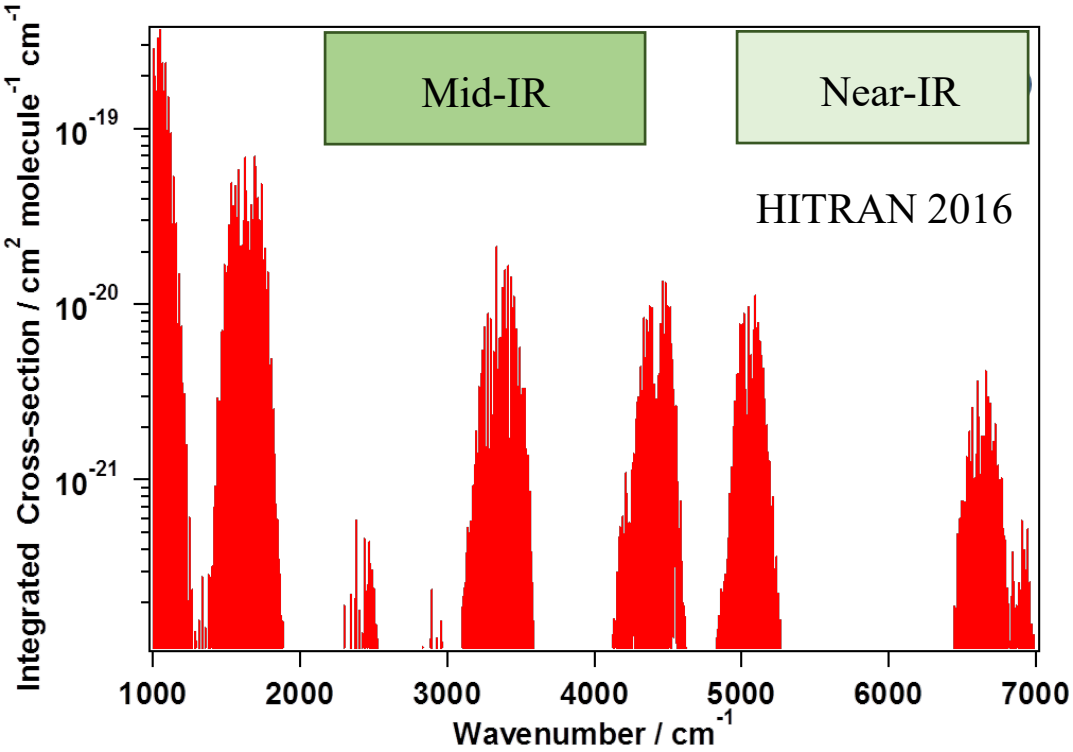


Potential sensor for NO,NH_3



NH_3 measurements using laser absorption spectroscopy

NH_3 concentration can be quantified without interference of other species, when the appropriate absorption line is selected.



Mid-IR

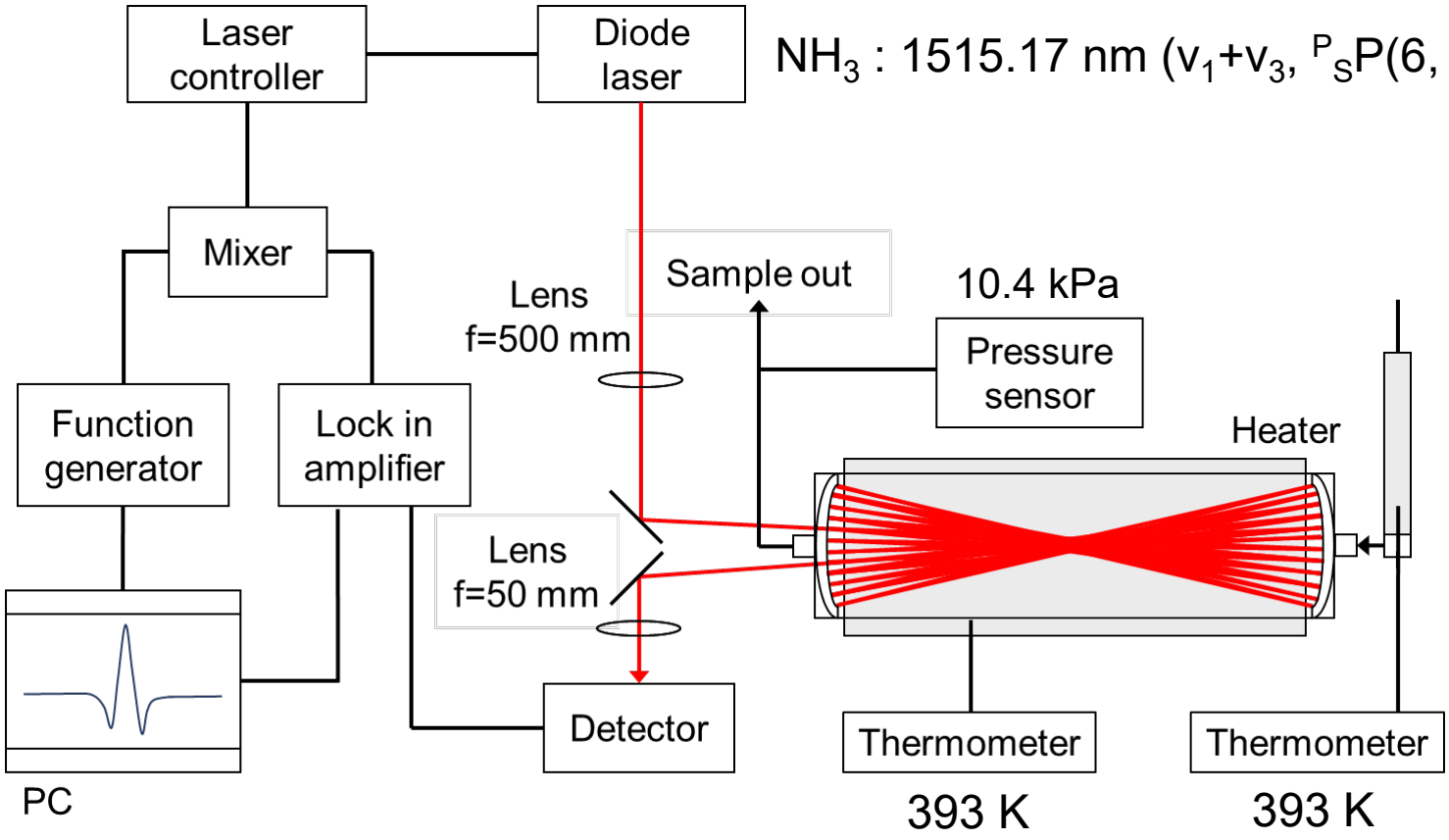
FT-IR,
QC-LAS

Near-IR: Compact and relatively low-cost light source.

Suitable for on board measurements

Compact measurement system with WMS etc.

Ammonia measurement system using near-infrared laser spectroscopy



Cell volume (L)	0.9
Temperature (K)	393
Total pressure (kPa)	10.4
Time resolution (s)	1

Instruments size
450 mm × 600 mm × 180 mm

Picture of optics in near-IR laser based ammonia measurement system