NH_3 / N_2 / O_2 Non-Premixed Flame in a 10 kW Experimental Furnace
– Characteristics of Radiative Heat Transfer

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Outline

- Background
- Objective
- Experimental
- Results and Discussion
- Summary

Background

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Global Paris Agreement : Reduce the greenhouse gas emissions

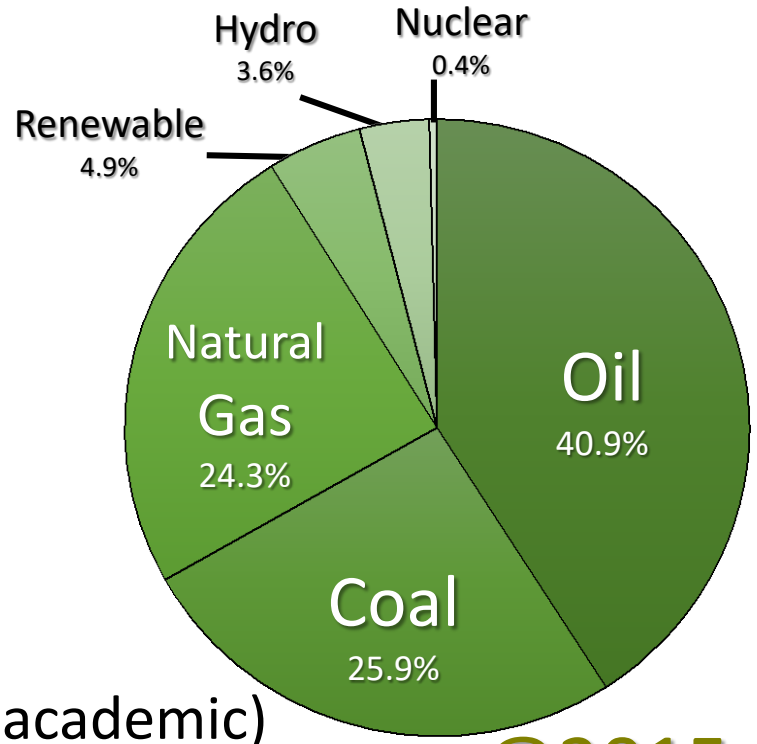
Japan CO_2 emissions : 26% reduction of 2013 by 2030

But!

After the Fukushima nuclear disaster in 2011

Primary energy supply in Japan depends greatly on the combustion of fossil fuel.（More than 90%）

Realize the Hydrogen based energy for CO_2 free society by 2030



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SIP*

All Japan dream team
(government, industry, academic)

*Cross-ministerial Strategic Innovation Promotion Program by Cabinet Office, Government of Japan

What is a Hydrogen based society ?

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Production | **Carriage** | **Utilization**

Reforming

Fossil Fuels (i.e., petroleum, coal)

(currently)

H_2

CO_2 Capture & Storage

Liquid H_2

Renewable energy

H_2

Hydrogen production by water Electrolysis Or heat

MCH

Ammonia

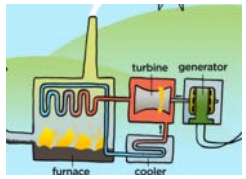
H_2

Ammonia

Direct combustion!

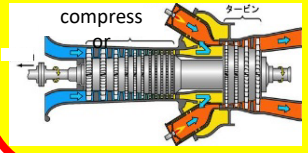
Fuel Cell vehicle

Fuel Cell System



Electric Generation

Industrial Furnace



Gas Turbine

Ammonia : carrier and also energy as a *Direct Combustion*

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Objective

- Advantages of ammonia
  - ✓ No CO_2 emission $4NH_3+3O_2 \rightarrow 2N_2+6H_2O$
  - ✓ Mass production
  - ✓ Transportation and storage
- Issues of ammonia
  - ✓ Low radiant heat flux due to no carbon (low heating efficiency)
  - ✓ Low laminar burning velocity (instable)
  - ✓ High NOx emissions

- Objective of this study

How is Ammonia combustion with enriched oxygen in a furnace?

- ✓ Higher radiative characteristics?
- ✓ Higher temperature?
- ✓ Stable?

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Experimental Apparatus ; 10kW test furnace

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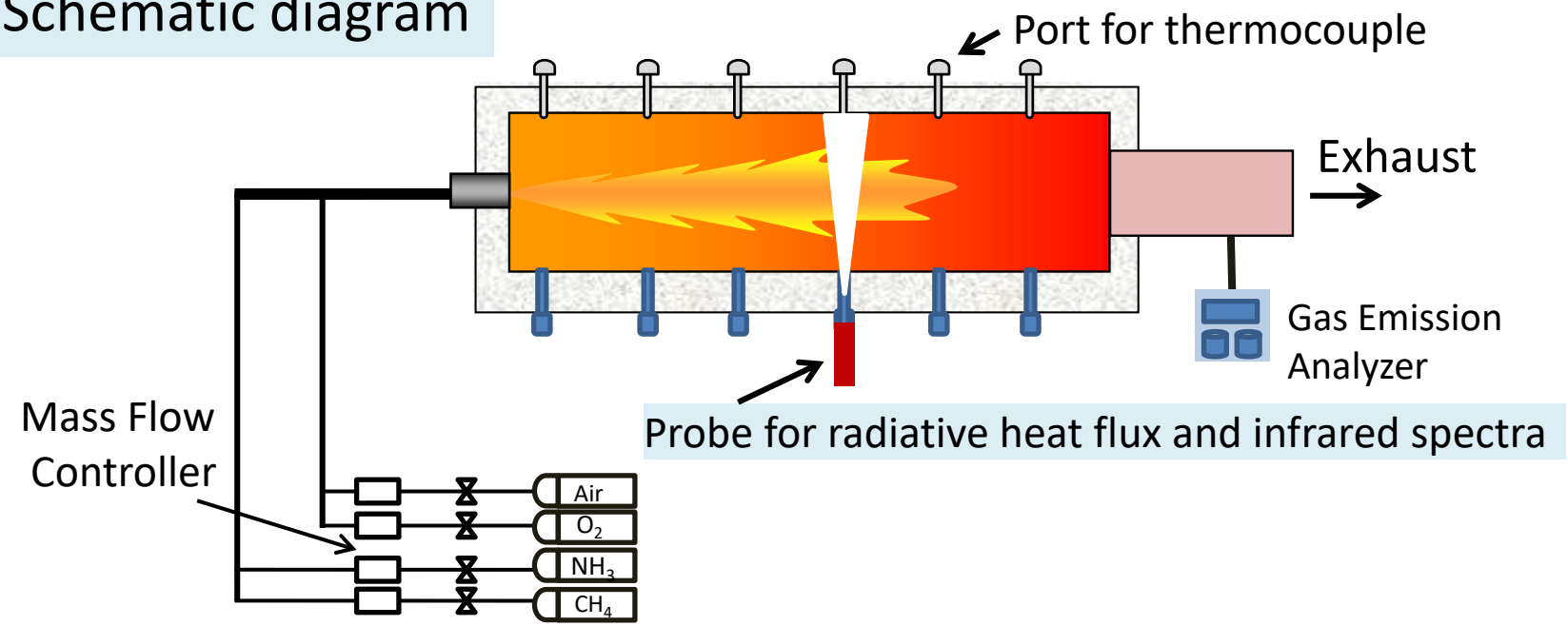
Photograph of 10kW test furnace

Schematic diagram



Experimental Apparatus ; Measurement probe

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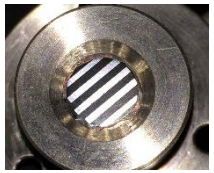
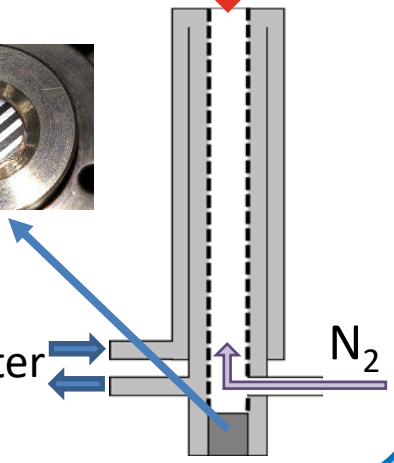
✓ Simple Radiative heat flux & IR spectrum measurement system

Probe for heat flux

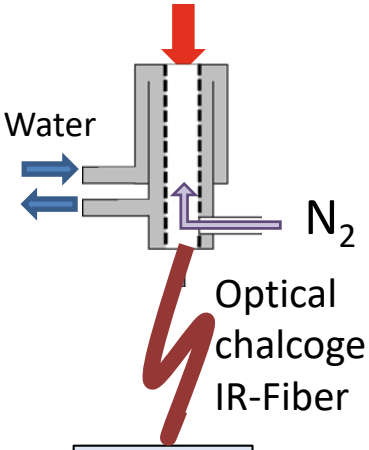
Radiative heat flux





Probe for IR Spectrum

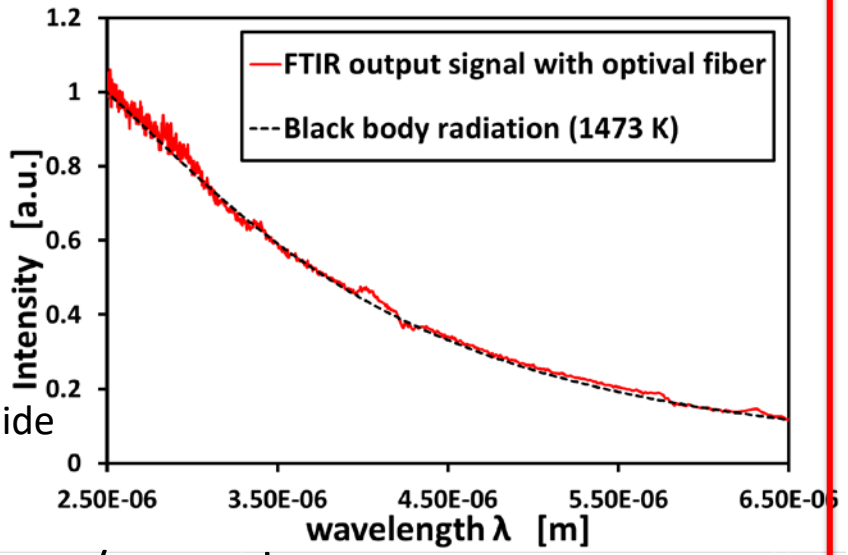
IR Spectrum



FTIR

100times/ second
(Arcoptix)

Calibrate the sensitivity
of the wavelength dependency
using a Block Body furnace



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Radiative heat flux and Temperature

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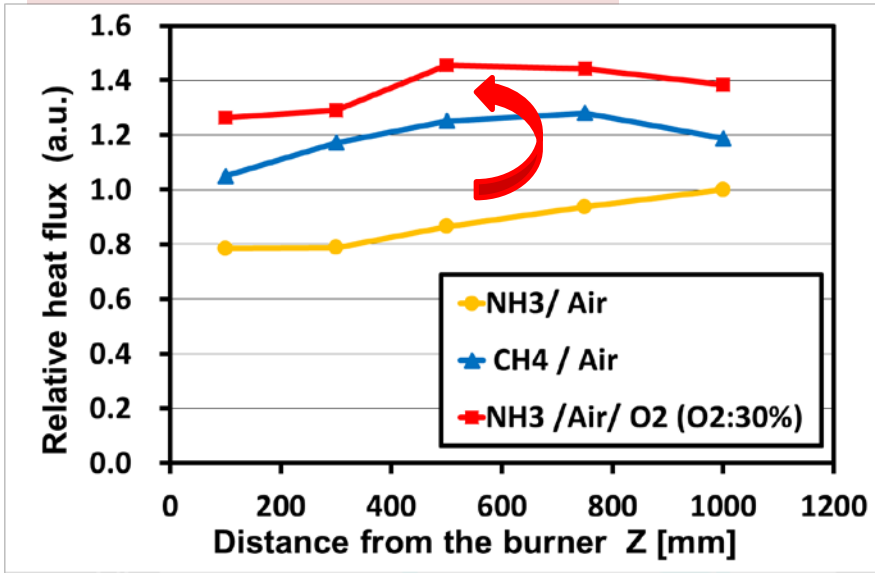
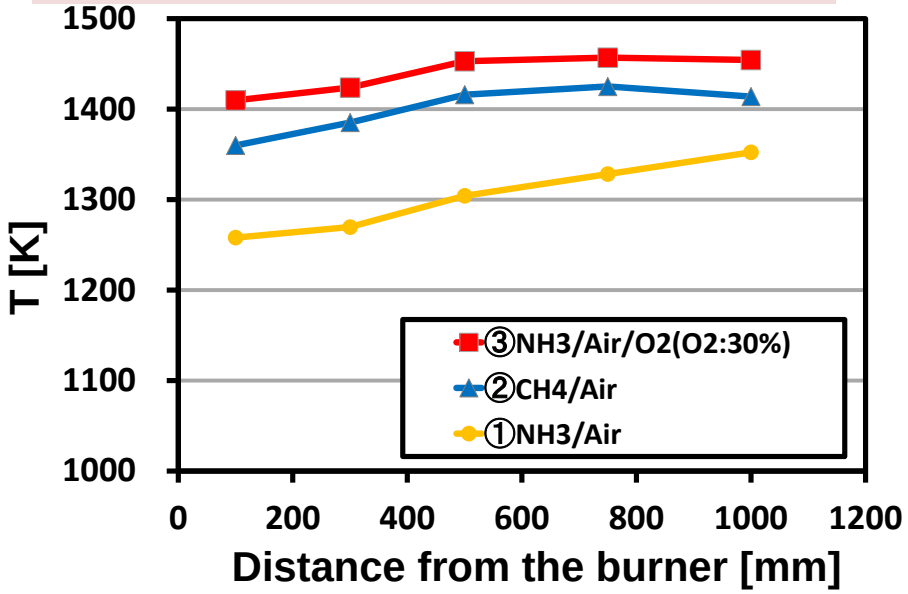
Experimental conditions

	Fuel	Air ratio (%)	O2 concentration in the oxidizer (vol. %)	Lower heating Value (kW)
①	NH3	1.05	21	10
②	CH4	1.05	21	10
③	NH3	1.05	30	10

Radiative heat flux distribution



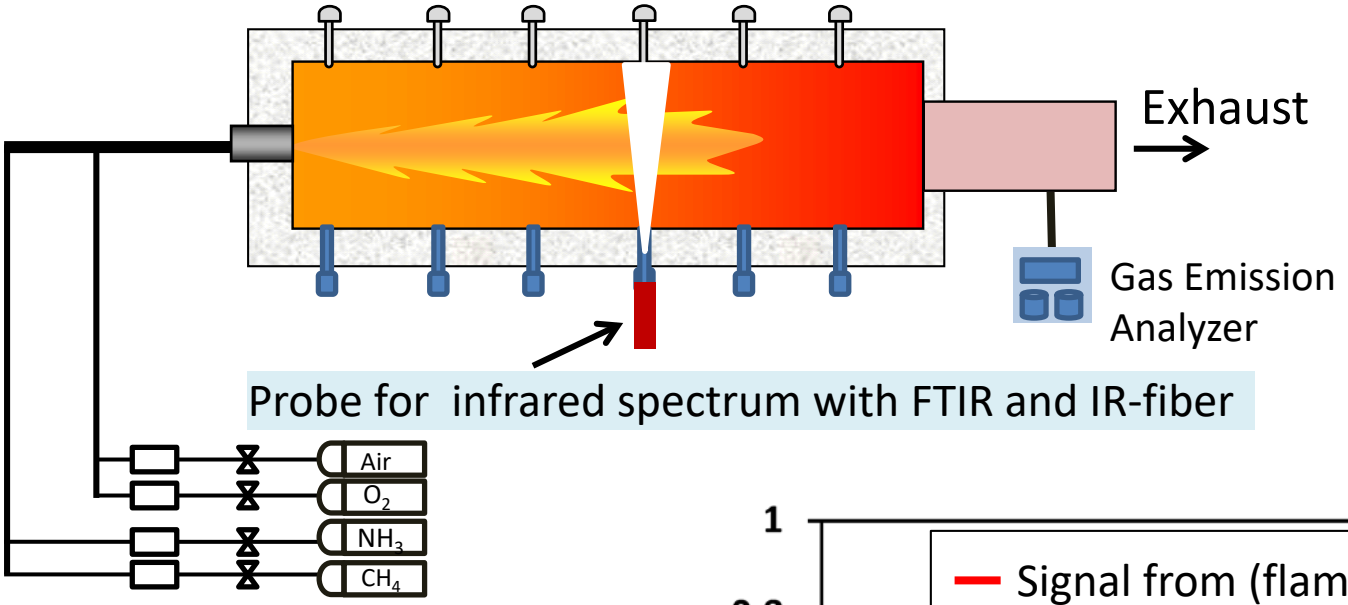
Temperature distribution inside the furnace



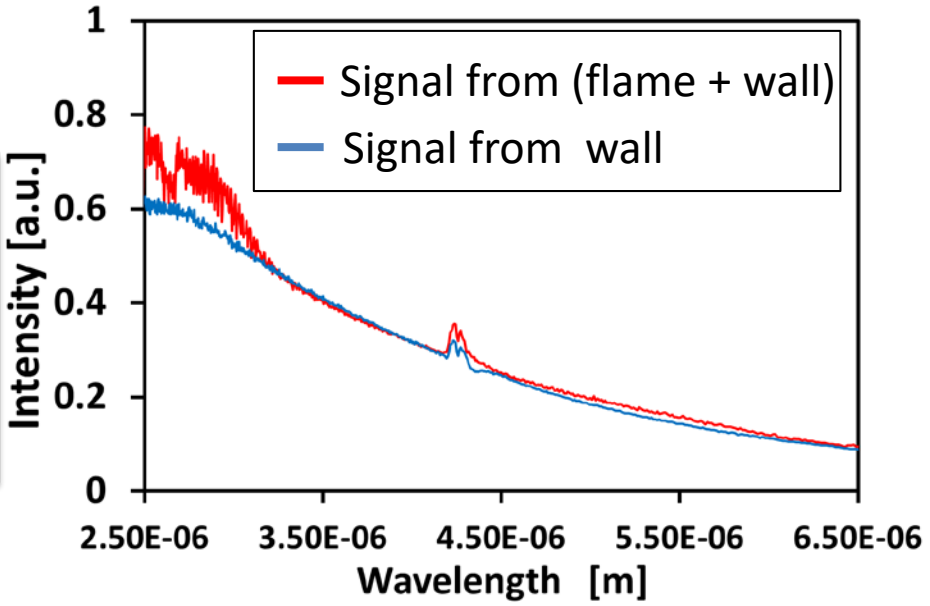
The 30 vol.% of O_2 enriched air concentration could result in the higher temperature and could produce 1.4 times total heat flux compared with the combustion in the methane/air condition.

IR spectrum measurement 1

- 95% of heat flux doesn't come from frame but furnace wall.

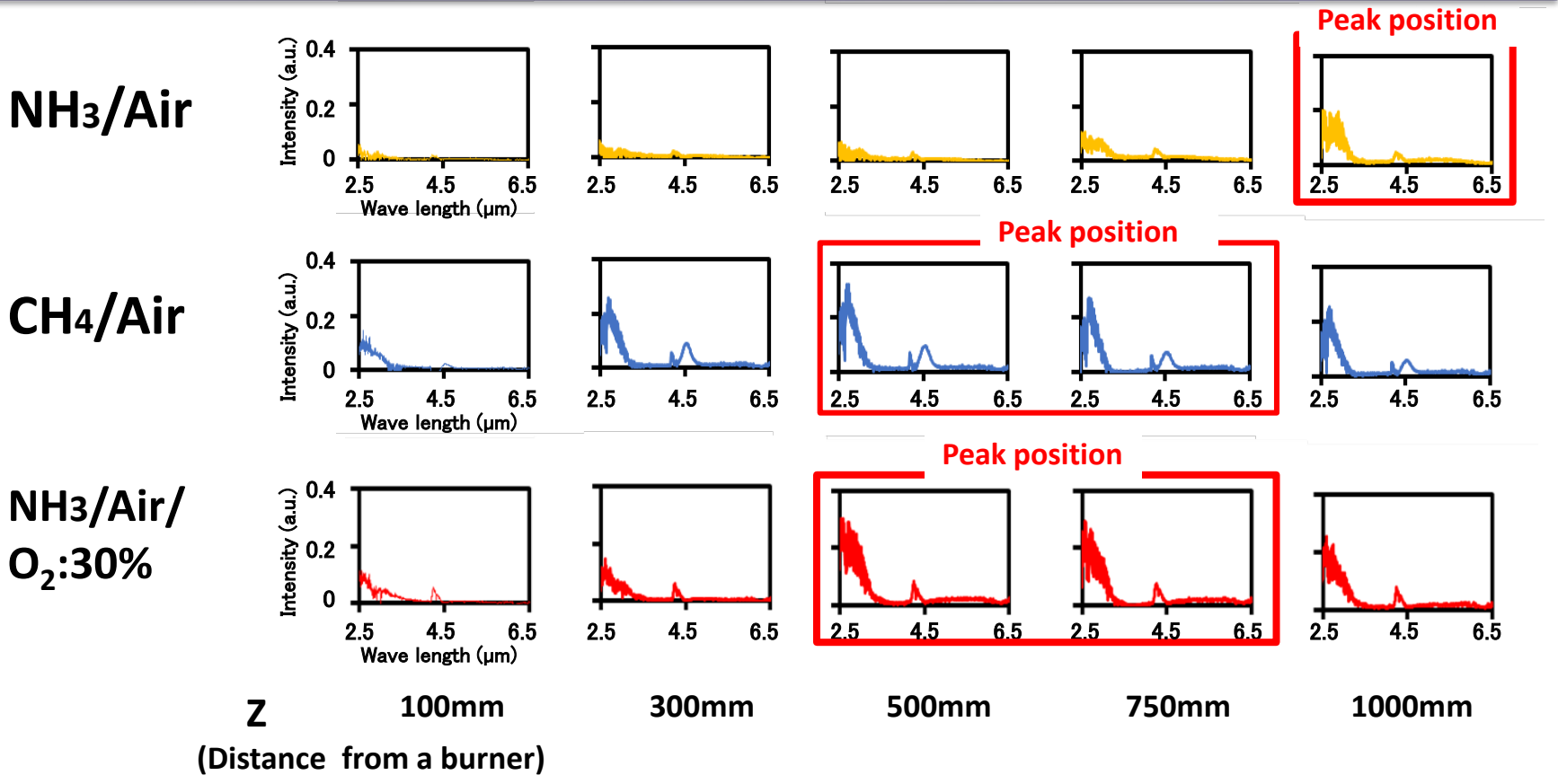


● IR intensity generated by flame
= (total signal at 1354K) – (signal in case of turn off combustion at 1358K) , Z=1000mm



Result of IR Spectrum 2

- The intensity of spectrum around 2.7μm decrease due to H2O and CO2 in case of NH3 combustion.
- The peak position of the radiative heat flux in ammonia combustion shitted to the downstream region
- The oxygen enriched combustion can shorten the distribution of the radiative heat flux and put the peak position of it toward a nozzle region.



Conclusion

◆We developed the simple spectrum measurement system and the heat flux probe.

◆**The 30 vol.% of O_2 enriched air concentration** could result in the higher temperature and could produce 1.4 times total heat flux compared with the combustion in the methane/air non-premixed condition.

We showed the probability that a direct combustion of ammonia can be applied to a realistic usage in an industrial furnace.

Acknowledgement

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Thank you for kind attention.

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