FR09 (Kyoto)
Dec. 7, 2009

Development of high sensitive and reliable FFD and sodium leak detection technique for fast reactor using RIMS

C. ito[a], Y. Araki[a], Y. Iwata[a], H. Naito[a] and T. Aoyama[a,b]

[a] *Experimental Fast Reactor Department (Joyo), Japan Atomic Energy Agency*

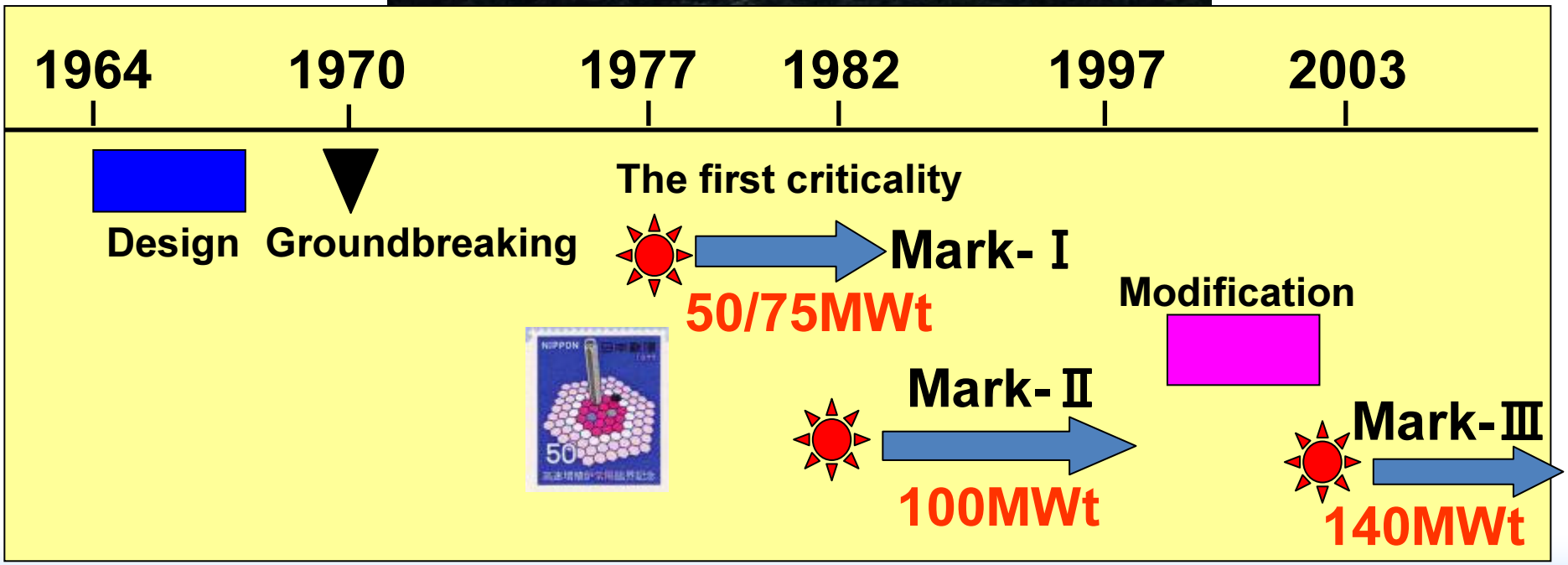
[b] *Research Institute of Nuclear Engineering (RINE), University of Fukui*

RIMS: Laser Resonance Ionization Mass Spectrometry

History of Joyo 常陽

Role of Joyo Mark-III

Fuels and materials irradiation test
MA and LLFP transmutation
Research and development for SFR on safety
Student education and training



Introduction

Failed Fuel Detection and Location (FFDL) and **sodium leak detection** are essential for SFR safety.

Conventional technique

FFDL: Tagging, Selector valve, Sipping (wet, dry)

Sodium leak detection: Sodium Ionization Detector (SID), Radiation Ionization Detector(RID), Contact Leak Detector (CLD)

more sensitive, simple, robust, reliable, ・・・

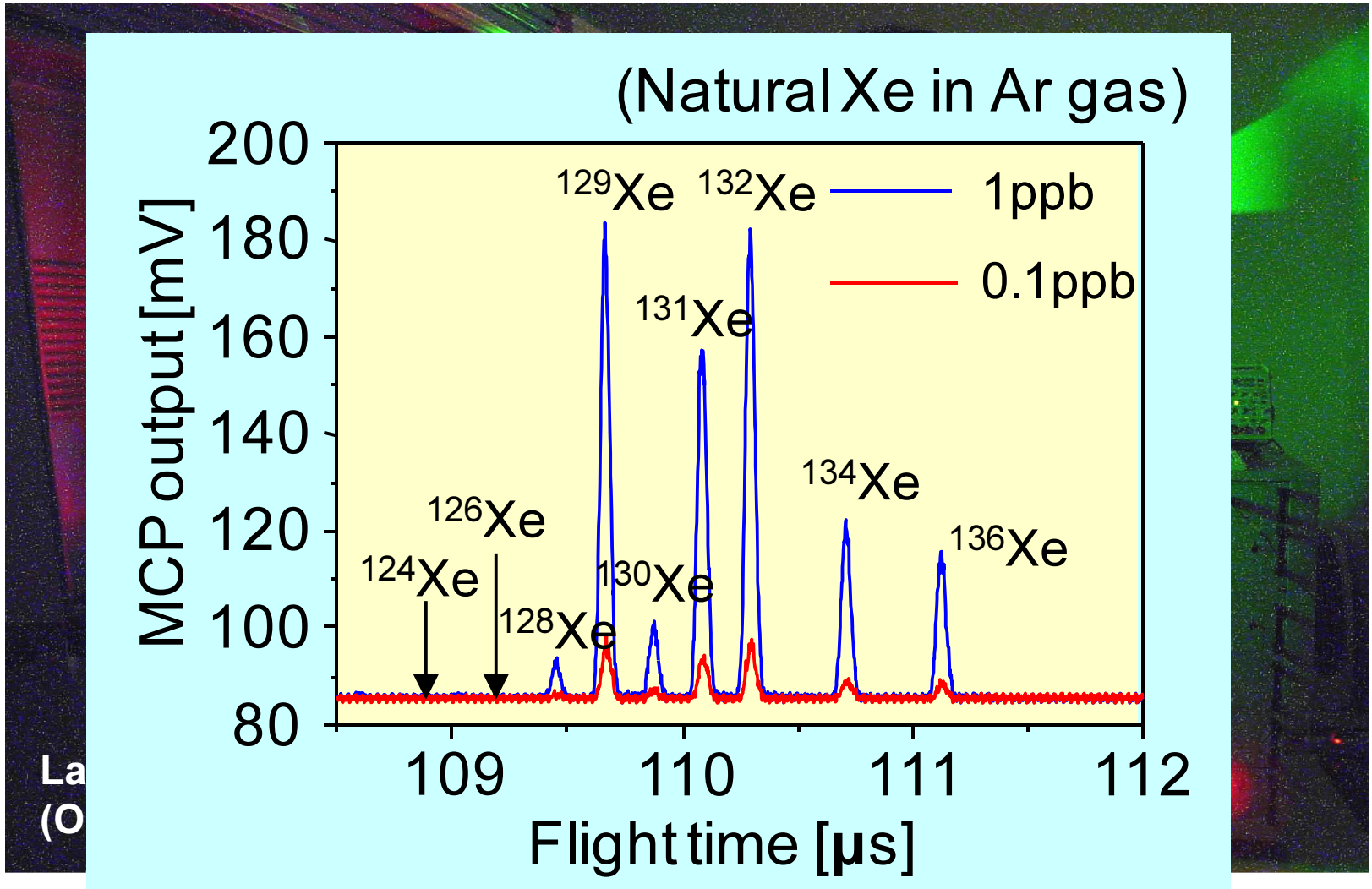
RIMS: Laser Resonance Ionization Mass Spectrometry

Ultra high sensitive (~ppt), Highly reliable (prevent from false signal)

Applied to

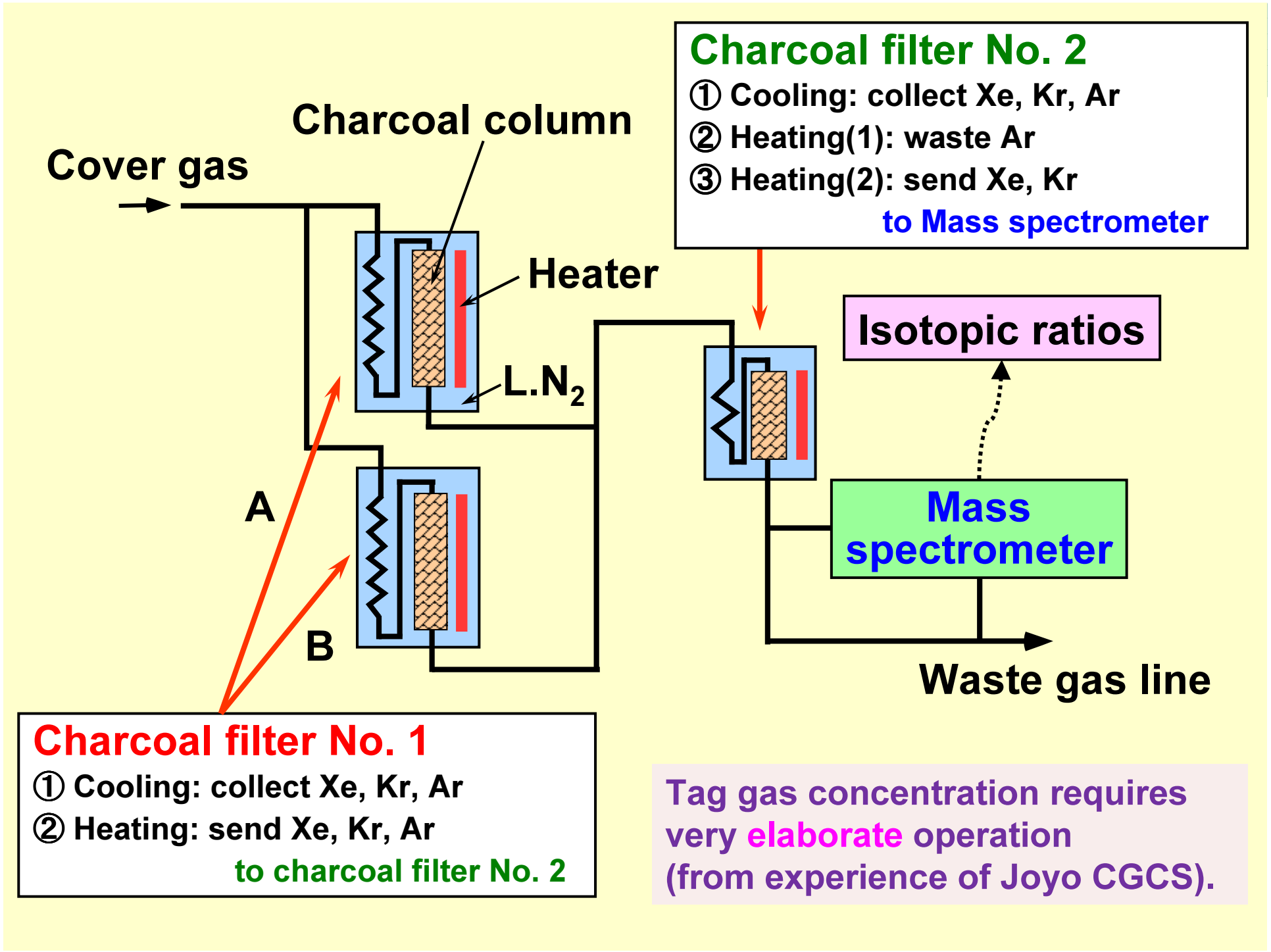
- FFDL by measuring Xe, Kr gas
- Sodium leak detection by measuring sodium aerosol

What is RIMS ?


(Natural Xe in Ar gas)
MCP output [mV]
200
180
160
140
120
100
80
109
110
111
112
Flight time [μs]
1ppb
0.1ppb
124Xe
126Xe
128Xe
129Xe
130Xe
131Xe
132Xe
134Xe
136Xe

Topics 1

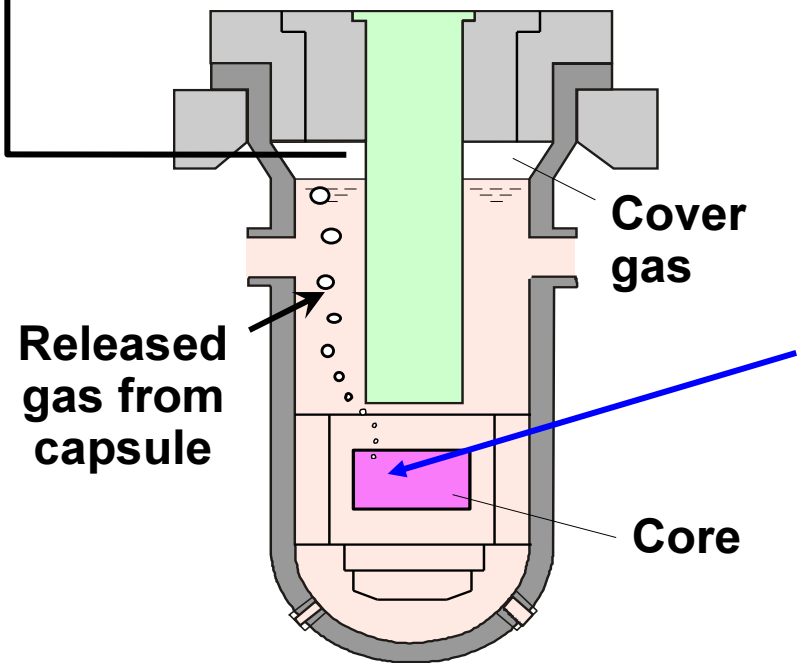
Failed fuel detection and location by RIMS


Charcoal filter No. 2
① Cooling: collect Xe, Kr, Ar
② Heating(1): waste Ar
③ Heating(2): send Xe, Kr
to Mass spectrometer
Charcoal column
Cover gas
Heater
L.N2
Isotopic ratios
A
B
Mass spectrometer
Waste gas line
Charcoal filter No. 1
① Cooling: collect Xe, Kr, Ar
② Heating: send Xe, Kr, Ar
to charcoal filter No. 2
Tag gas concentration requires very elaborate operation (from experience of Joyo CGCS).

Tag gas release experiments (Joyo)

Gas sampling ···→ RIMS (Off-line)

On-line γ-ray Monitor (OLGM)



Reactor vessel

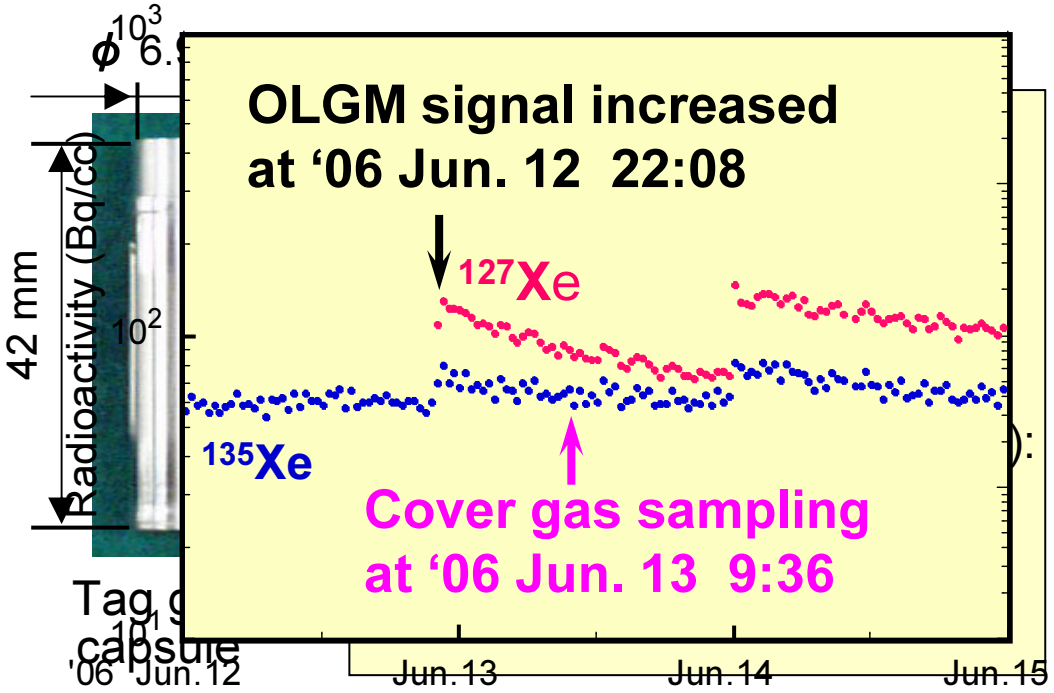
Procedure

1. Detect tag gas release

- Activated tag gas nuclides by **OLGM**

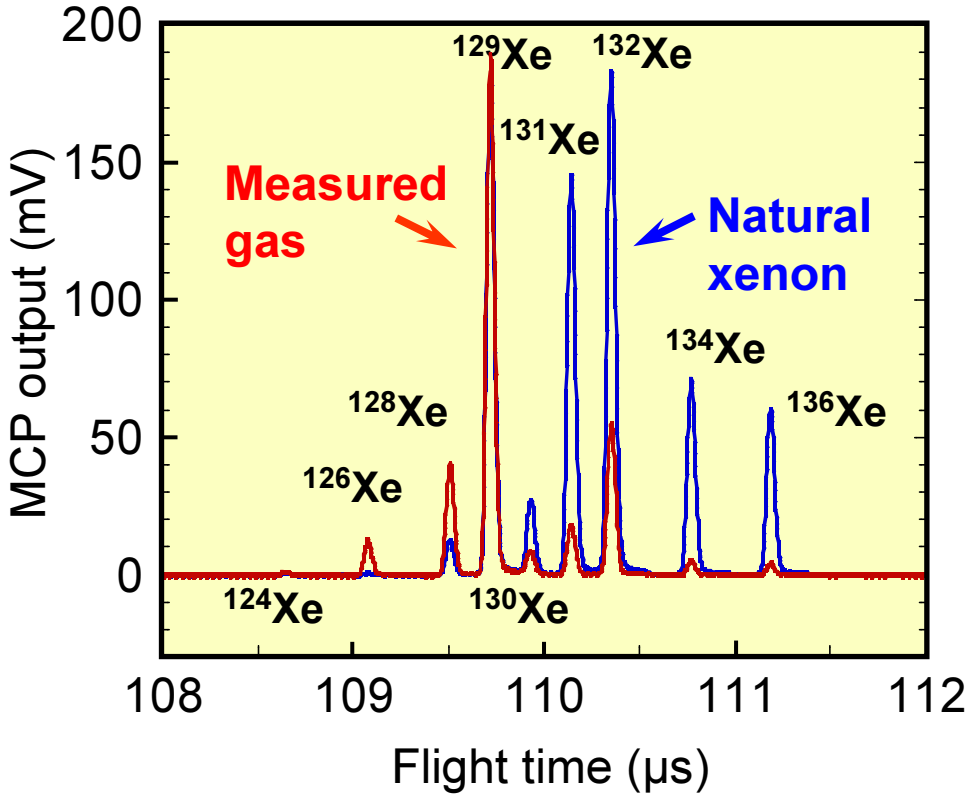
2. Identify ruptured capsule

- Isotopic ratios of tag gas by **RIMS**



Tag gas radioactivity in primary cover gas

Result of RIMS measurement



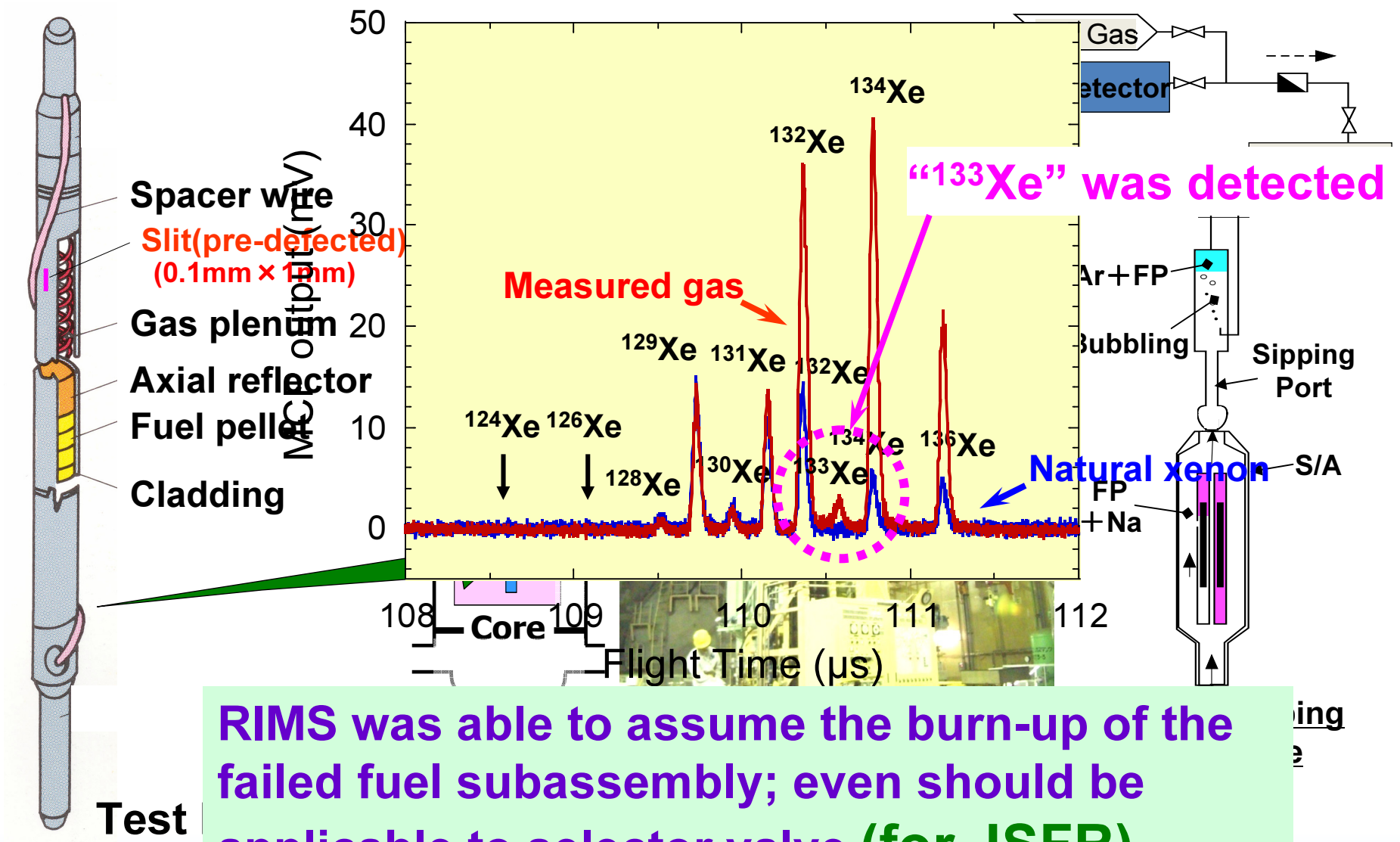
Mass spectrum by RIMS

Xenon isotopic ratios

Tag gas No.	$^{126}Xe/^{129}Xe$	$^{131}Xe/^{129}Xe$	$^{132}Xe/^{129}Xe$
1	0.632	0.896	0.891
2	0.069	0.101	0.298
3	0.209	0.890	0.101
4	0.630	0.301	0.101
5	0.629	0.102	0.892
6	0.071	0.888	0.889
by RIMS	0.065	0.099	0.295

Tag gas was successfly identified by measuring xenon isotopic ratios.

Fuel failure simulation test in Joyo (pre-defected at gas plenum)

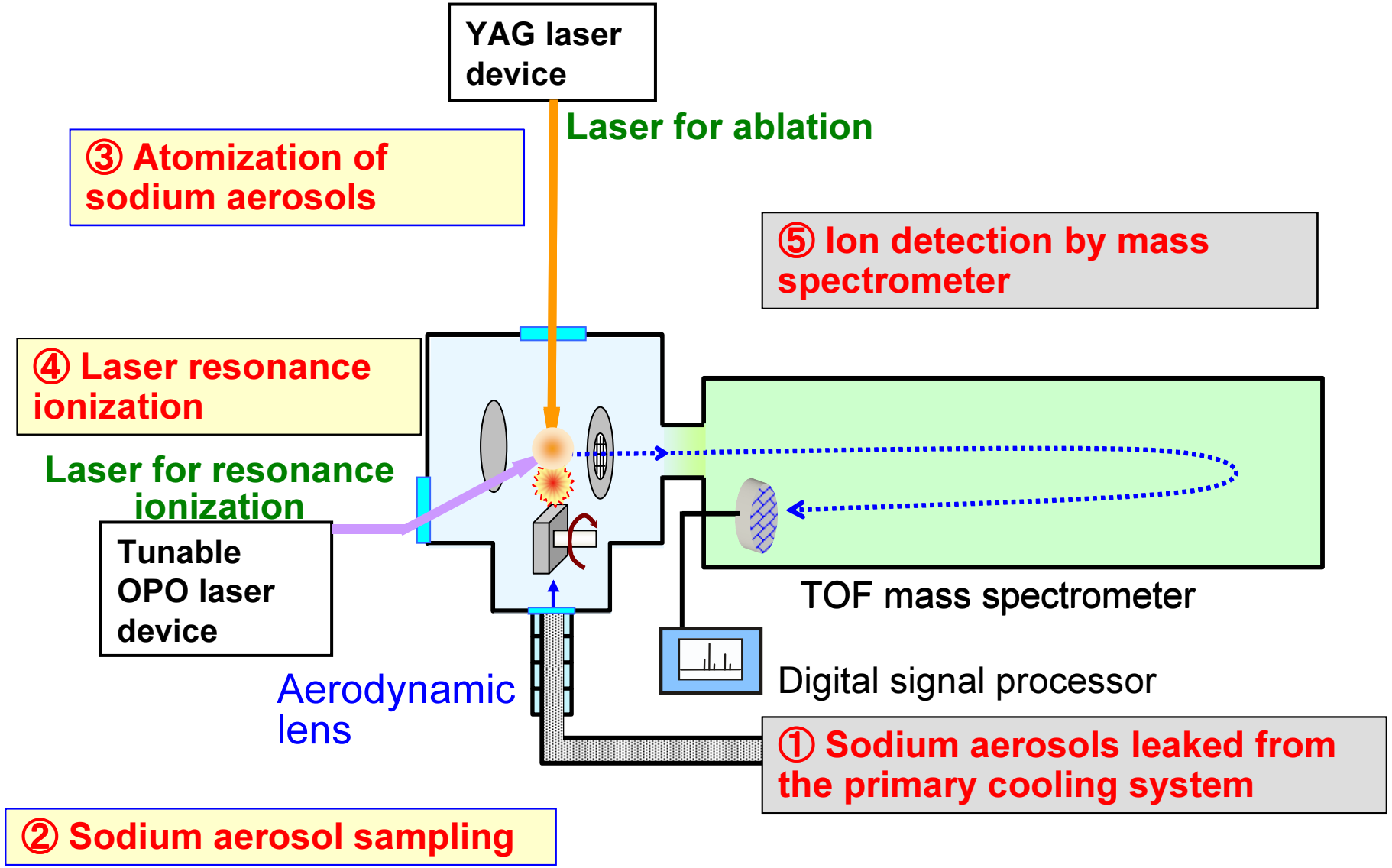


RIMS was able to assume the burn-up of the failed fuel subassembly; even should be applicable to selector valve (for JSFR).

Topics 2

Detection of small amount of sodium leak by measuring sodium aerosol

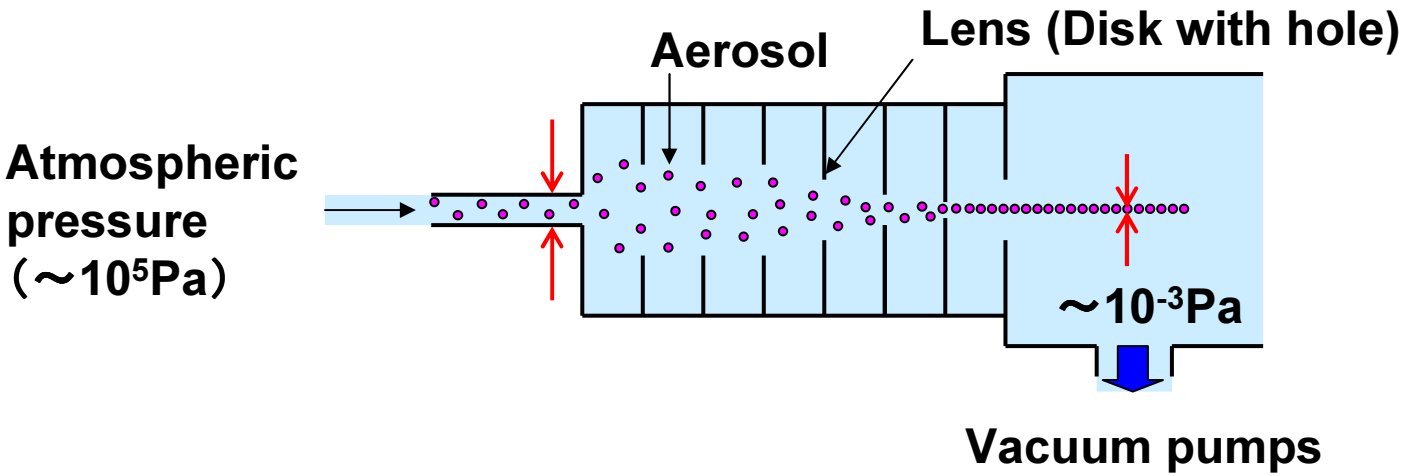
Sodium leak detection process



Sodium Aerosol Sampling

Aerodynamic lens was applied.

This has been measuring air pollution particles.



Advantage

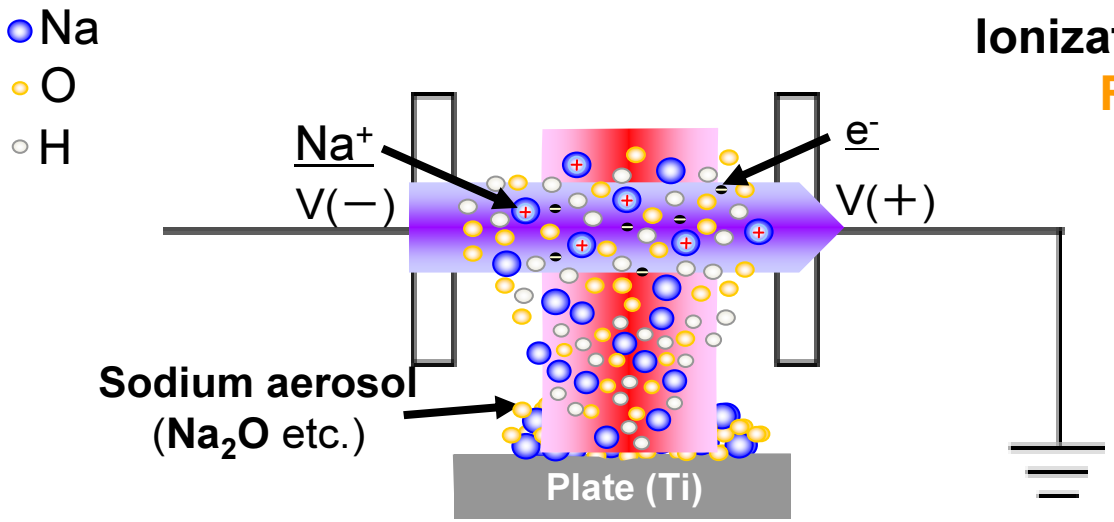
- Concentration of sodium aerosol (~ 10^7)
- More simple, robust than filter method

Atomization by laser ablation

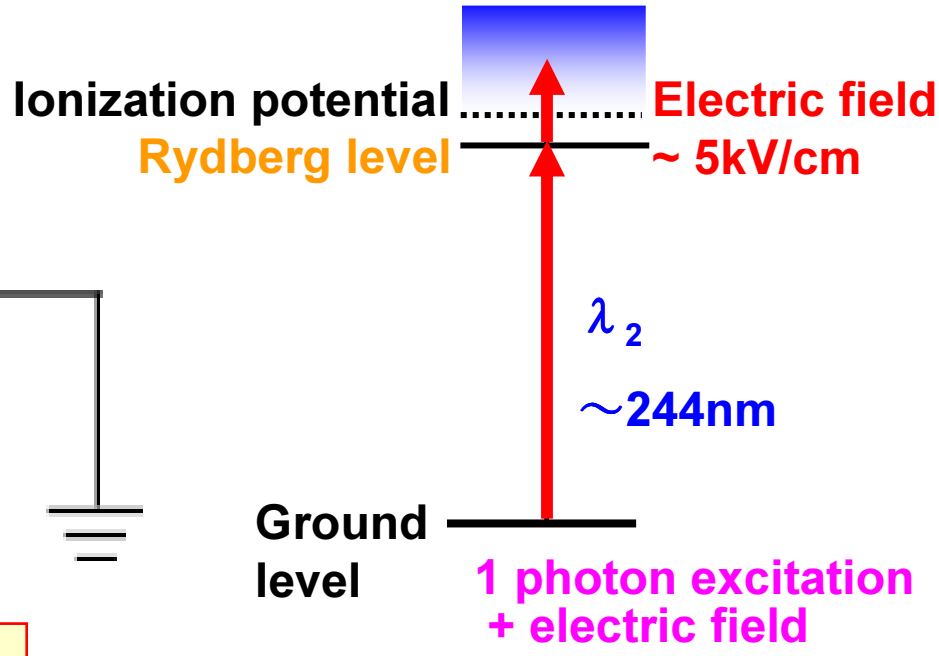
Temperature

- Electric Heater (furnace): ~10^3K
- Induced Coupled Plasma: ~7×10^3K
- Laser Ablation: ~10^4K

Laser ablation has advantage for atomization of various compounds: Na_2O, Na_2O_2, NaO_2, NaOH, Na_2CO_3 etc.

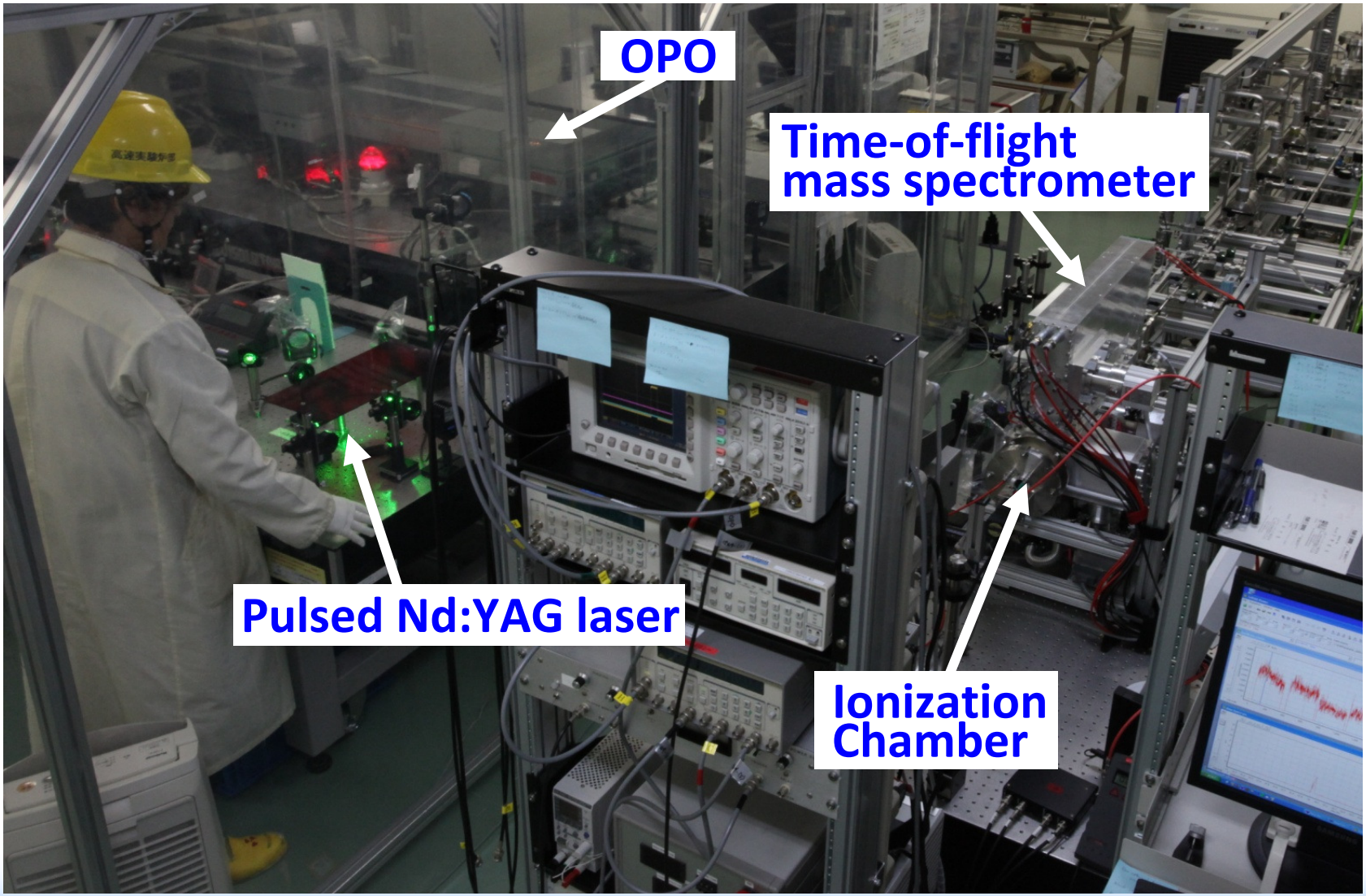


Ionization on the plate (titanium)

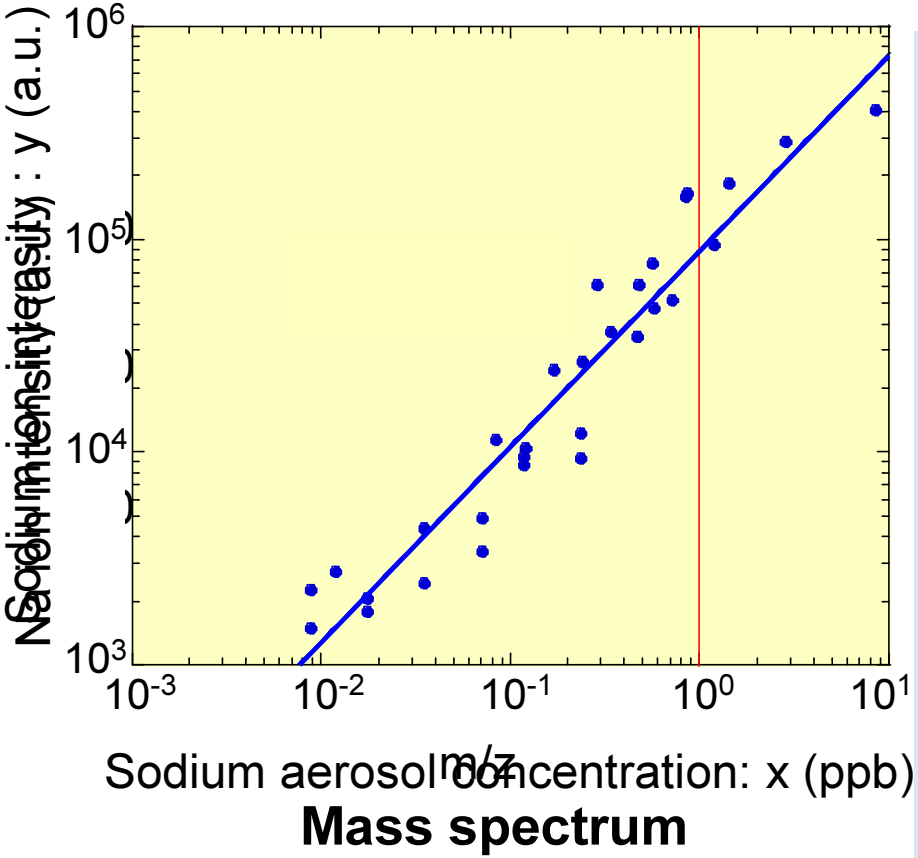


Ionization scheme

Prototype sodium aerosol detection system



Sodium aerosol detection experiments



Mass spectrum

- Peak of ^{23}Na was measured in high resolution.
- Linearity even in the row ^{23}Na concentration.
- Lower detection limit is **2.7ppt** .

Sensitivity:

400 times higher than the design target （**1 ppb**）

Summary

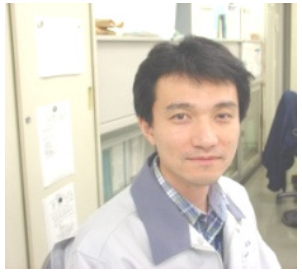
The high sensitive FFD and sodium leak detection technique for fast reactors has been developed using RIMS.

FFDL

- **Tag gas was identified with no concentration process.**
- **Burn-up of the failed fuel subassembly can be assumed.**

Sodium leak detection

- **Lower detection limit of ^{23}Na was achieved 400 times high sensitivity (2.7 ppt) higher than the design target (1 ppb).**

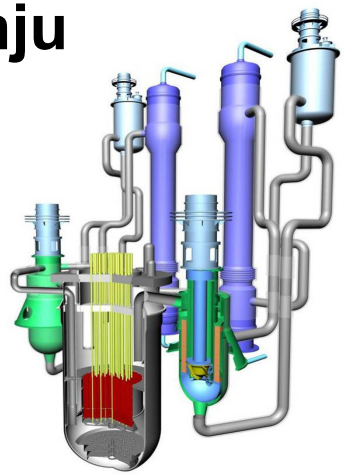





RIMS researchers in Joyo

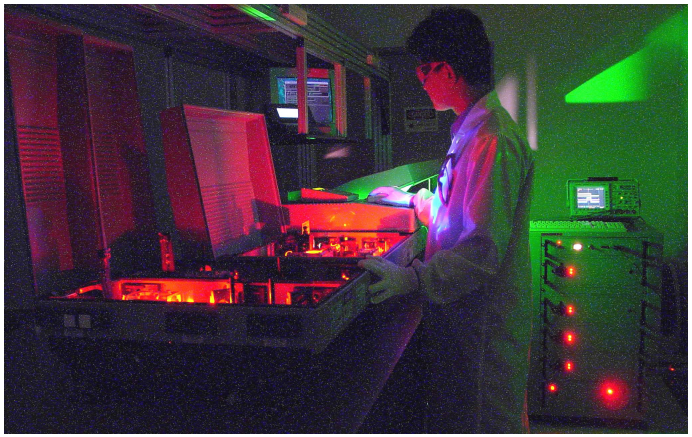
RINE

Monju



JSFR

Gen-IV



The RIMS system is expected to be a promising innovative instrumentation system for future SFRs.

This study includes the research entrusted by **the MEXT of Japan**.

The mark from the poem by Lucius Annaeus Seneca drawn on the operation floor of containment vessel

“The time will come, when our posterity will wonder that we have only now just realized such a self-evident truth .” ➡ **RIMS**