Development of multi-turn time-of-flight mass spectrometers

Jun Aoki, Michisato Toyoda
Osaka University

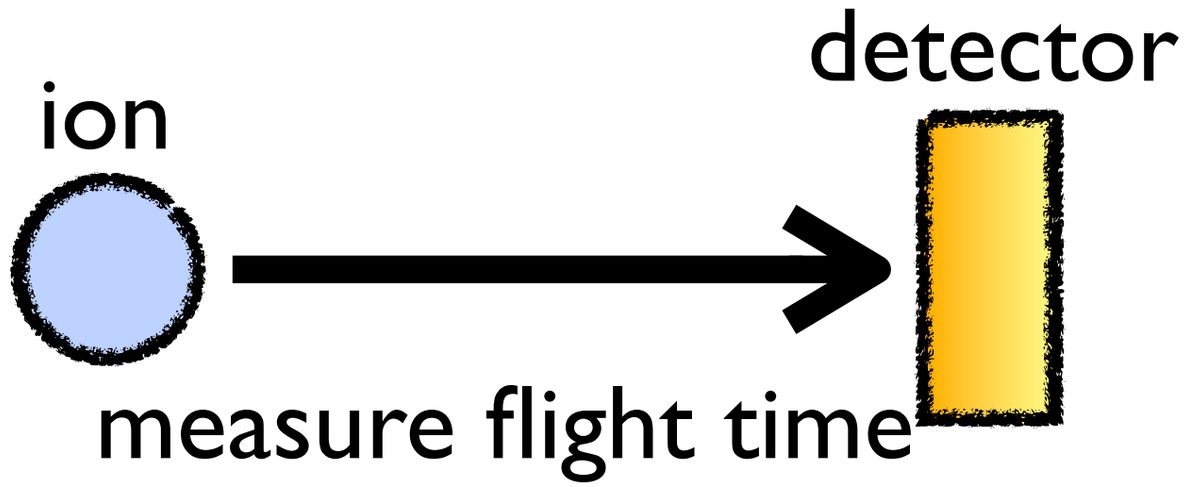
OSAKA UNIVERSITY

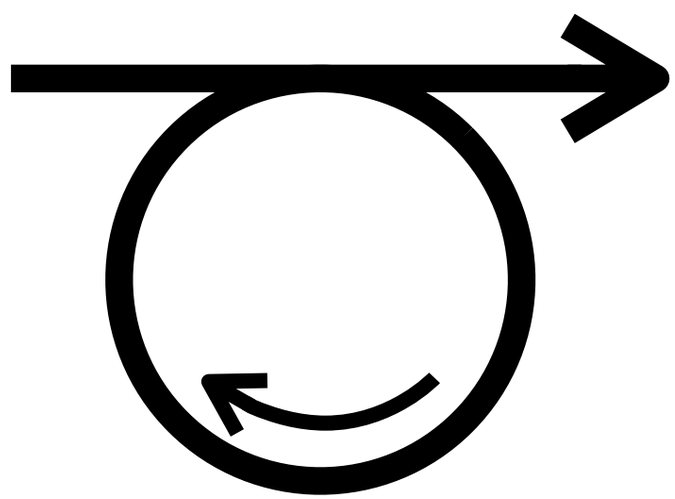
Physics
OSAKA UNIVERSITY

Outlines

1. Introduction
2. Ion Optics
3. Applications
4. Conclusion

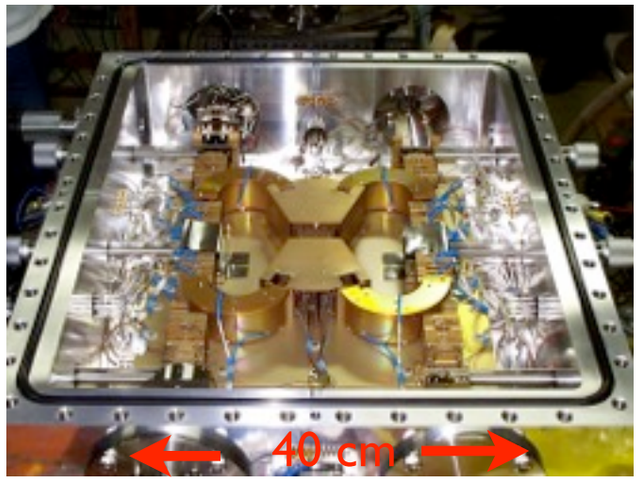
Multi-turn time-of-flight (TOF) mass spectrometer





First laboratory model for ROSETTA

1996 - 2001 Grant in Aid for Scientific Research (B)



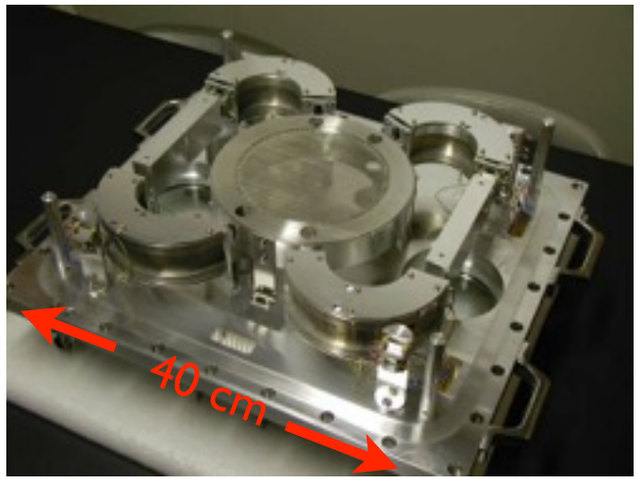
"MULTUM Linear plus"

J. Mass Spectrom., 38 (2003), 1125-1142.

Simplify

Second laboratory model for ROSETTA

1999 - 2002 Grant in Aid for Scientific Research (B)



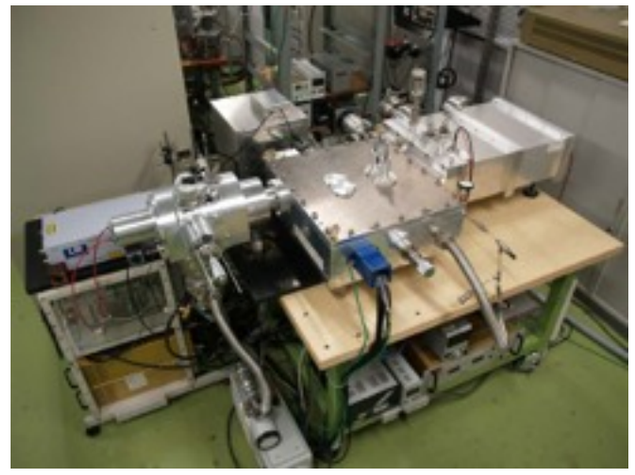
"MULTUM II"

J. Mass Spectrom., 38 (2003), 1125-1142.

MS/MS

Tandem TOF mass Spectrometer

2004 - 2006 Grant in Aid for Young Scientists (A)

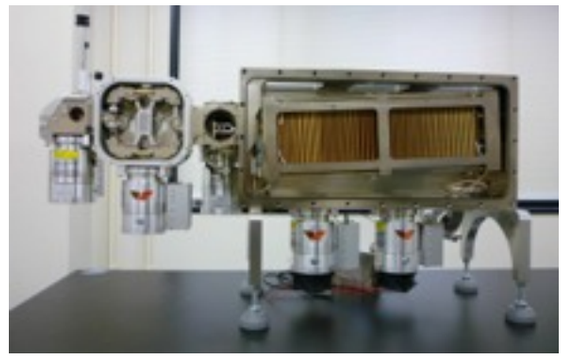


"MULTUM TOF/TOF"

Rev. Sci. Instrum.,78 (2007), 074101

2008～

Innovative Project for Advanced Instruments, Renovation Center of Instruments for Science Edu and Technology, Osaka University



2007 - 2008 JST Supporting Program for Creating University Ventures

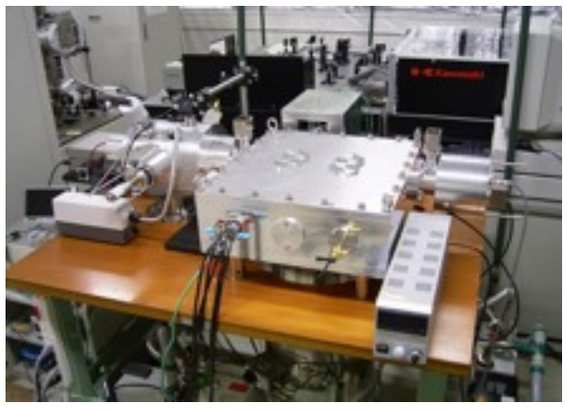
University Venture
MSI.TOKYO, Inc.

Miniaturize

Imaging MS

For imaging mass spectrometry

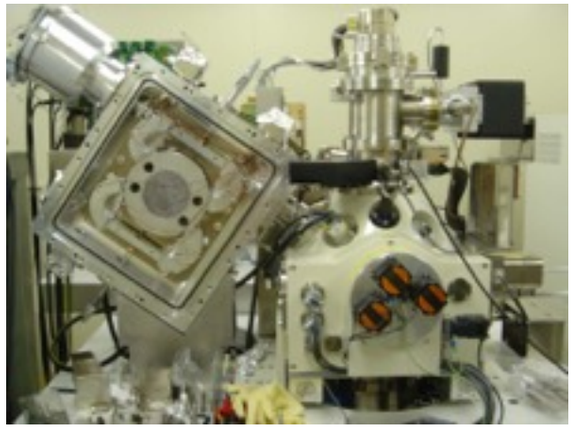
2005～2010 CREST



"MULTUM-IMG"

J. Biomed. Opt., 16 (2011), 046007.

2005 - 2008 Grant-in-Aid for Creative Scientific Research

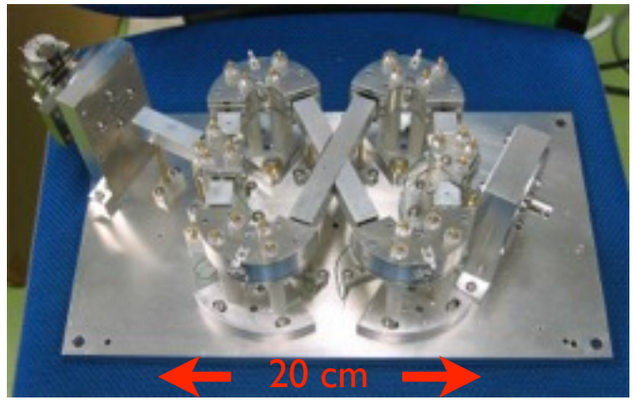


"MULTUM-SIMS"

Surf. Interface Anal., 42 (2010), 1598–1602.

Smaller instrument

2003 - 2005 constructed in workshop of Osaka Univ.



"MULTUM-S"

J. Mass Spectrom. Soc. Jpn., 55 (2007), 363-368.

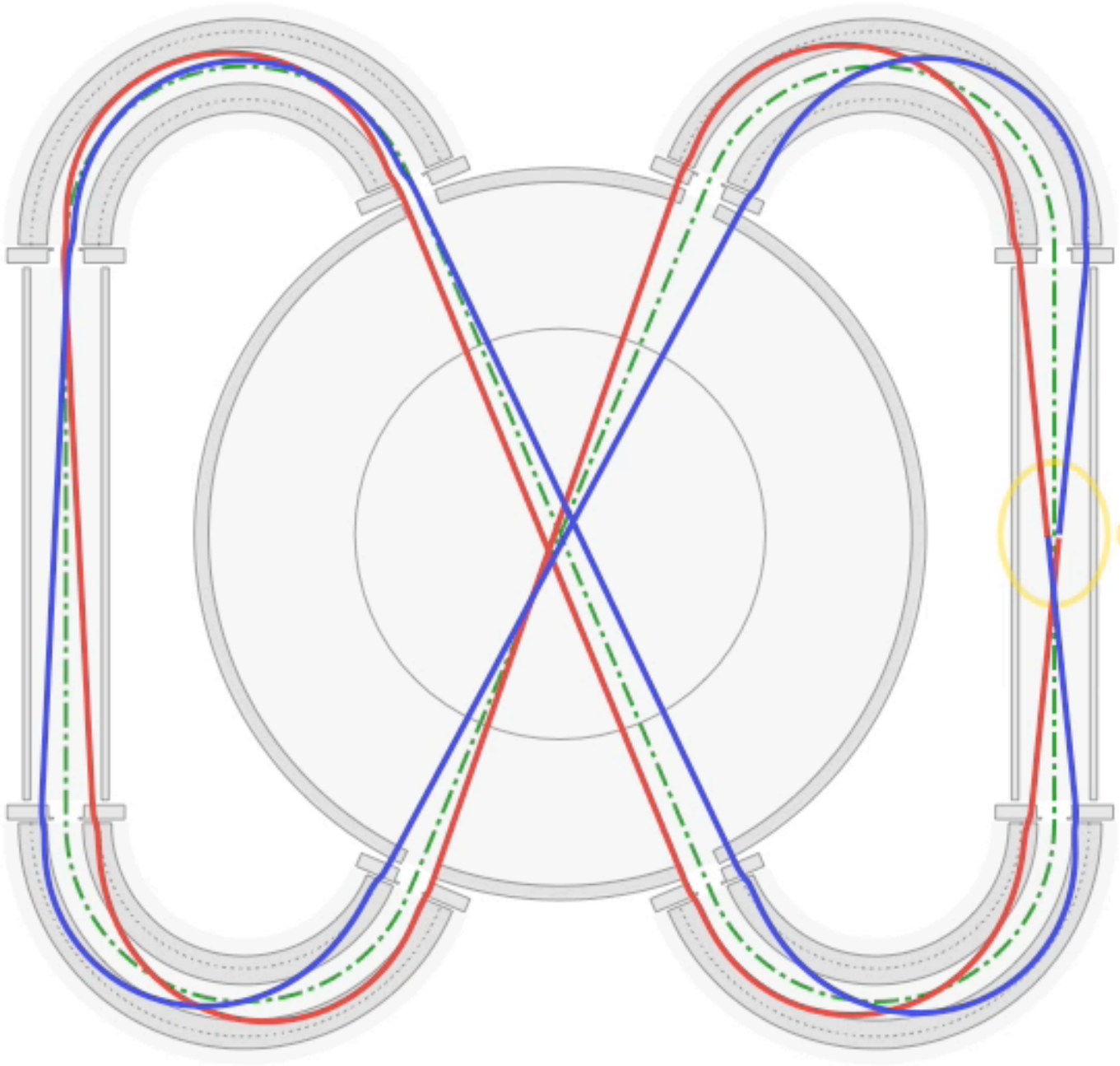
Compact instrument

"MULTUM-S II" -> infiTOF

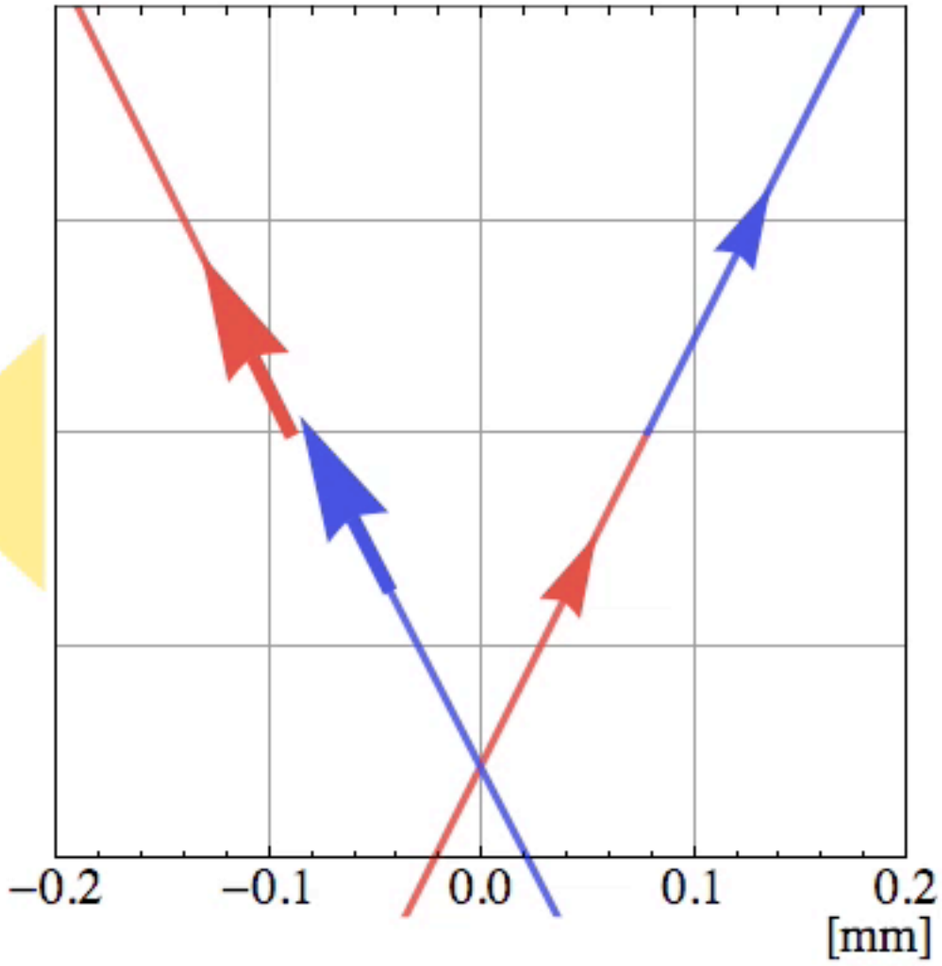
Anal. Chem., 82 (2010), 8456.

For future space missions

MULTUM's optics



Spatial Focus

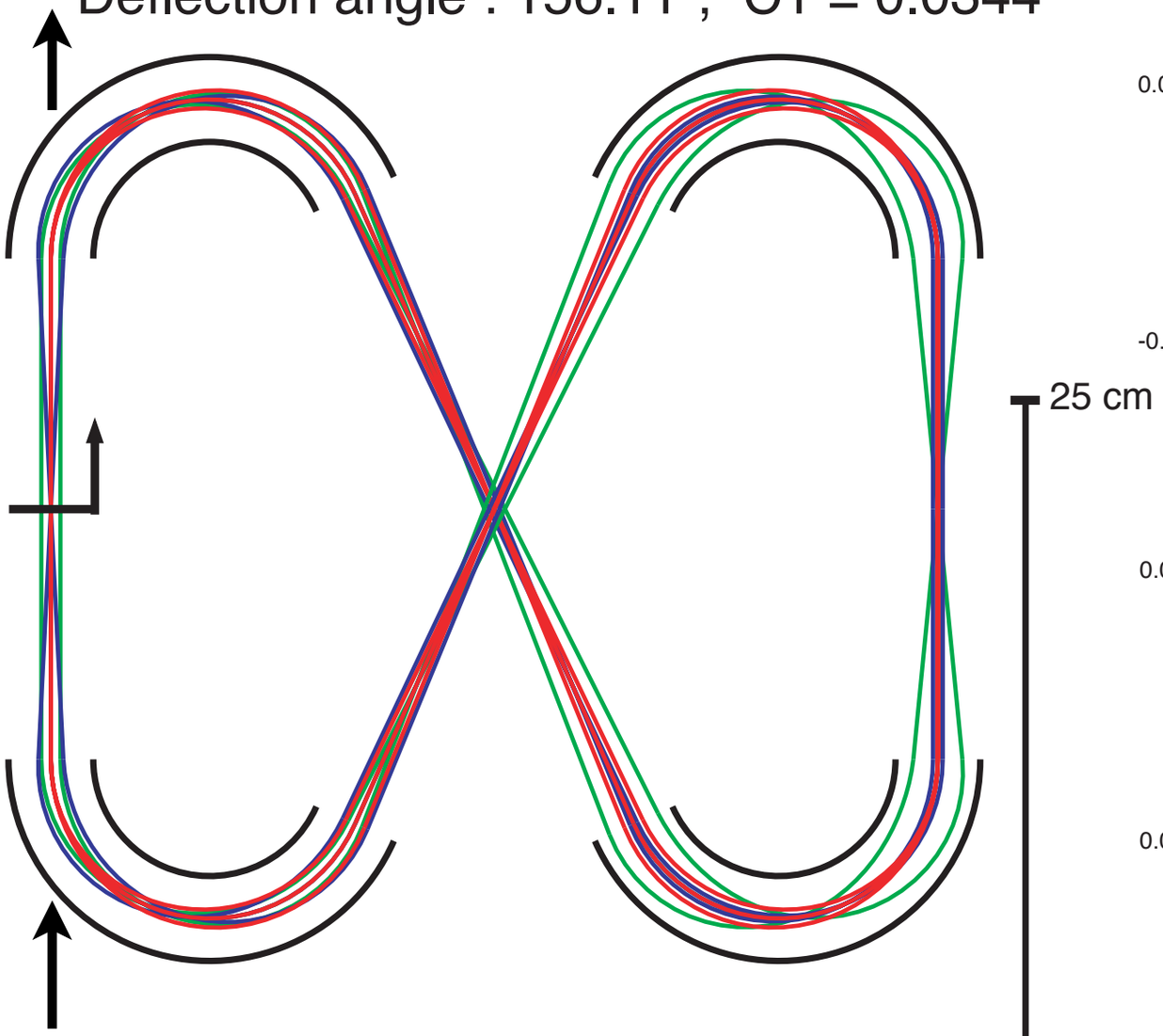


Ions return in same position and angle after 2 cycles.

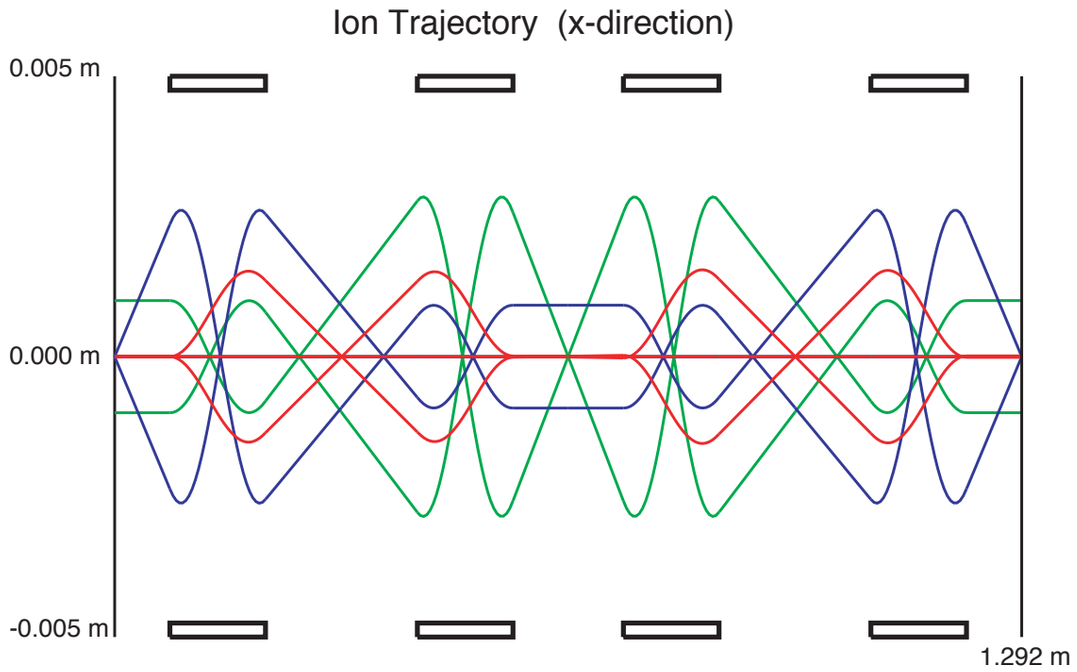
Ion Trajectories of 'MULTUM II'

Toroidal Electric Sector

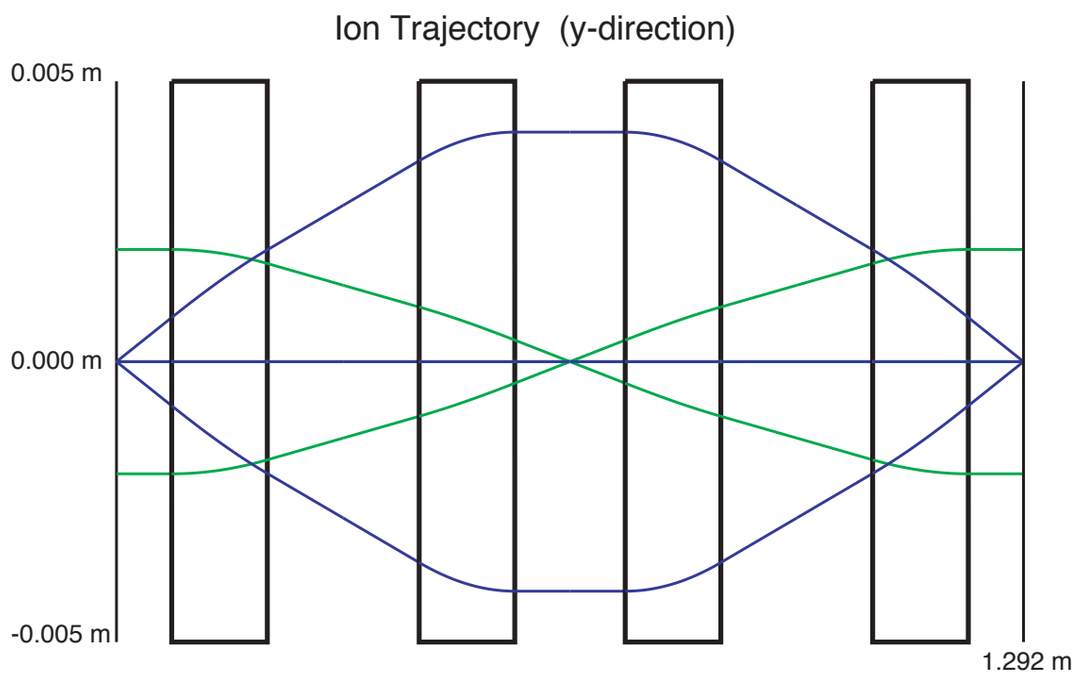
Deflection radius : 50 mm,
Deflection angle : 156.11°, C1 = 0.0344



x max = 0.0030 m , α max = 0.0500
γ max = 0.0000 , δ max = 0.0700

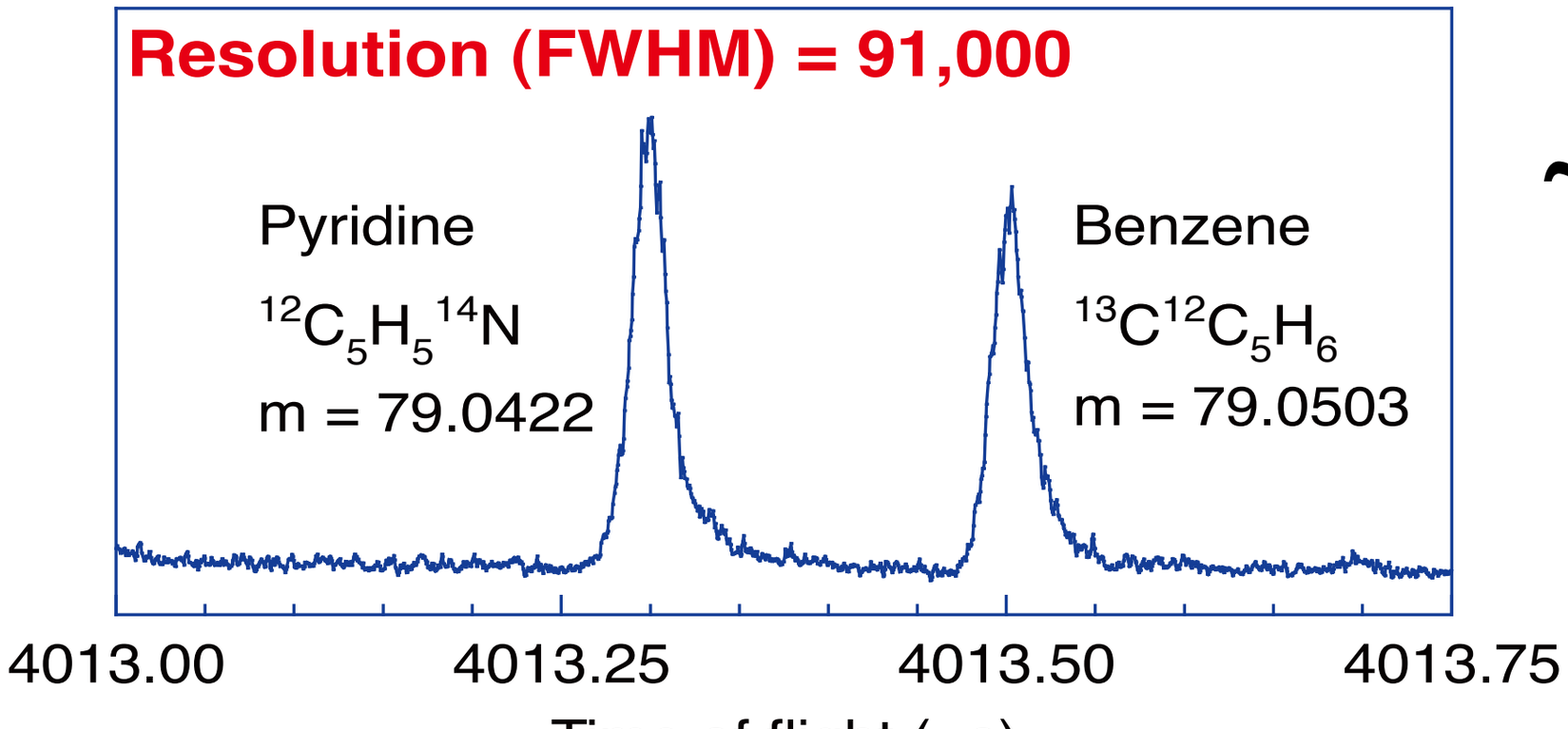


x max = 0.0010 m , α max = 0.0300, γ max = 0.0000 , δ max = 0.0300

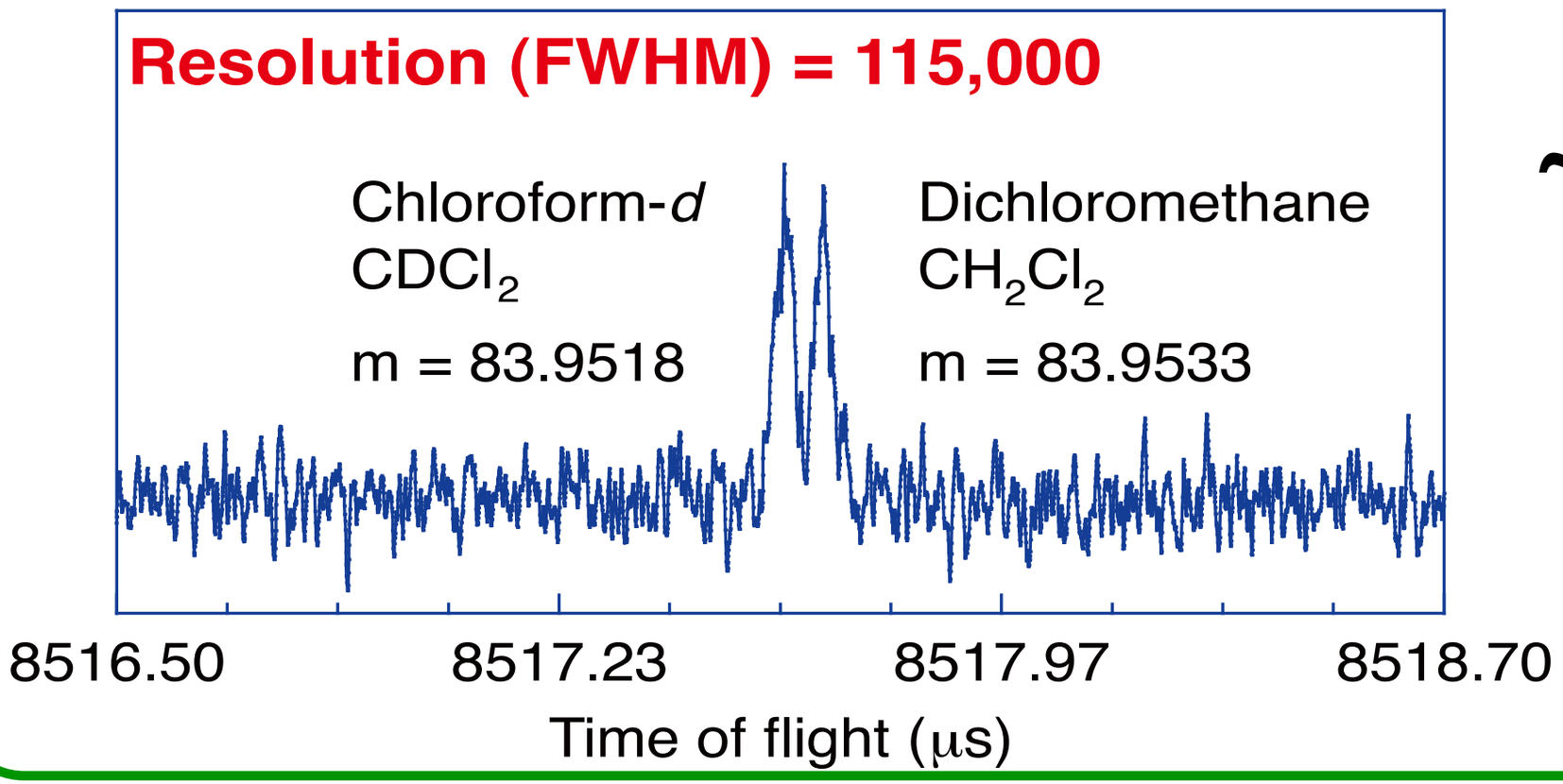


y max = 0.0020 m , β max = 0.0100

High resolution EI TOF Spectra



~300 cycles



~660 cycles

D. Okumura, et al.,
Eur. *J. Mass Spectrom.*,
11 (2005), 261.

Applications

- MULTUM-S II
- MULTUM-IMG

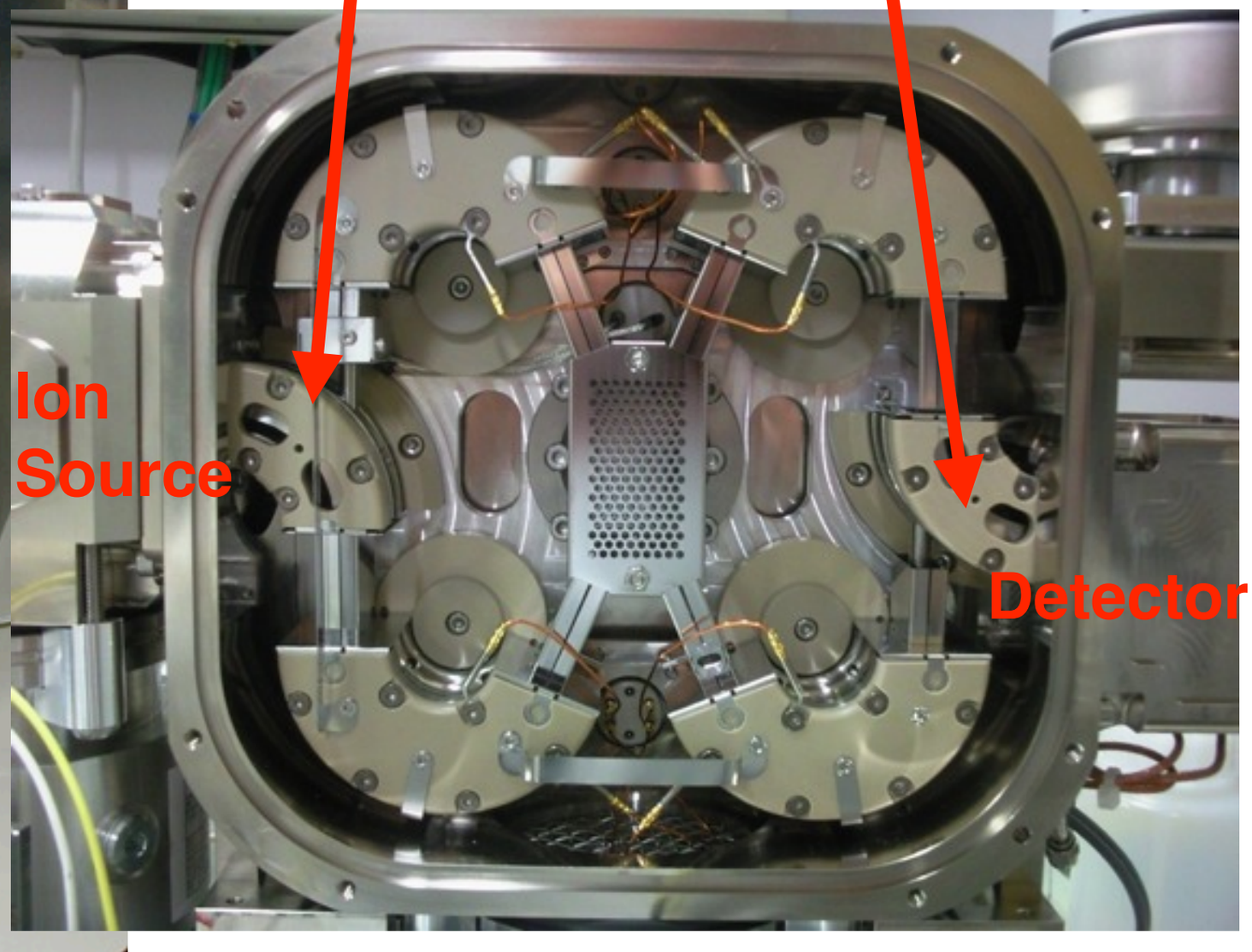
Miniature Multi-turn TOF Mass Spectrometer

“MULTUM-S II”

supported by University Venture Project,
Japan Science and Technology Agency (JST)

S. Shimma, et al., *Anal. Chem.*, **82** (2010), 8456-8463

Photograph of improved instrument “MULTUM -S II”

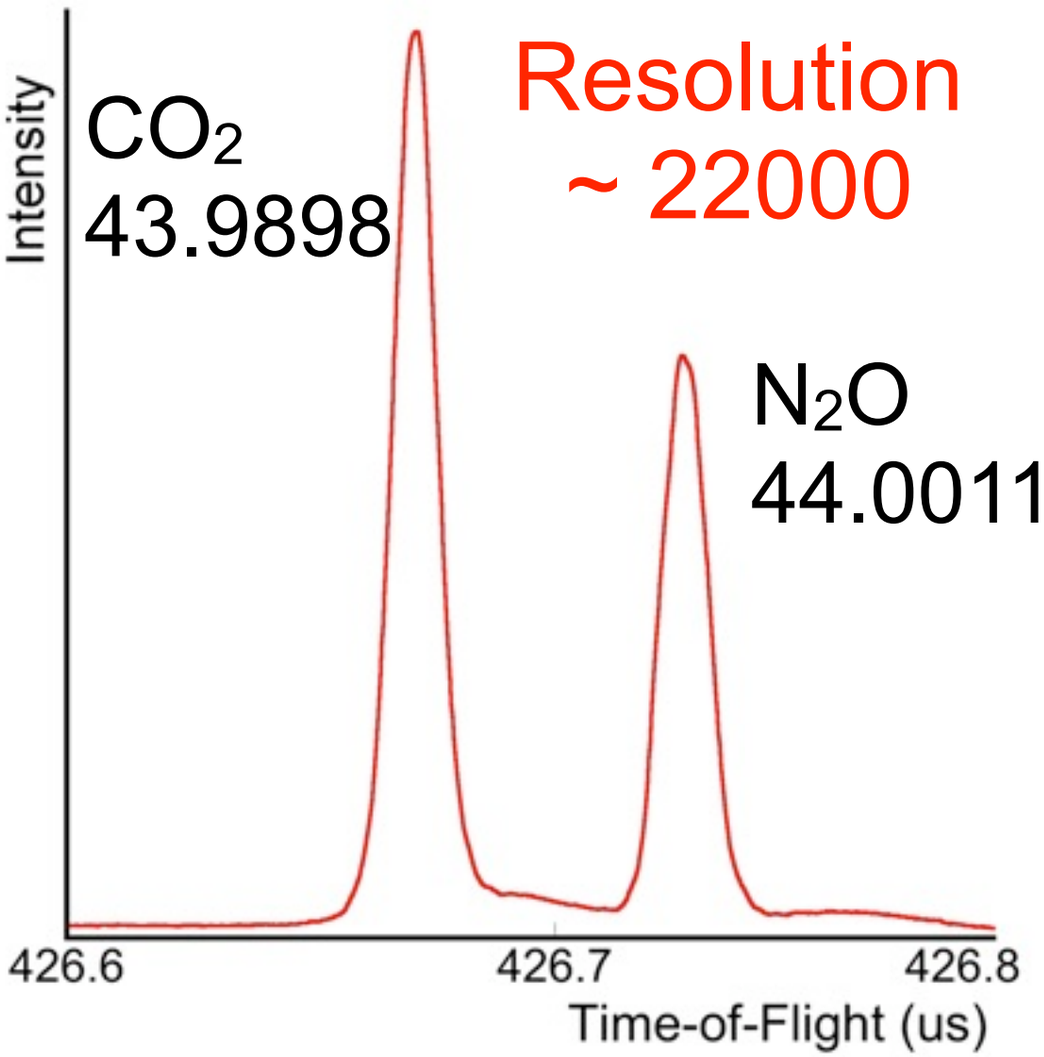


50 (H) cm × 30 (W) cm × 60 (D) cm, 35kg

Results of MULTUM-S II

CO_2 - N_2O doublet

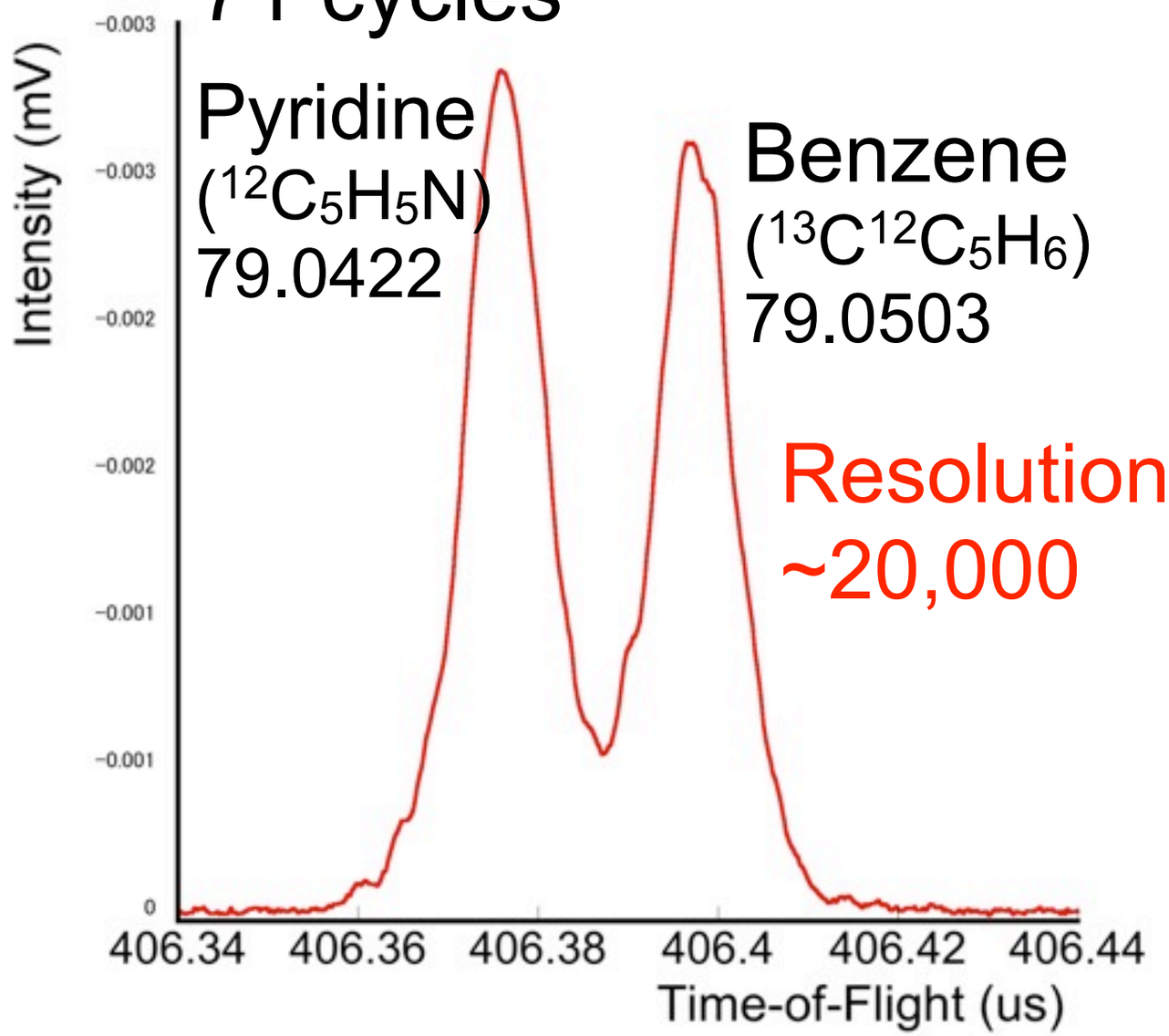
98 cycles



Resolution
~ 22000

Pyridine - Benzen doublet

71 cycles



Resolution:
~20,000

This instrument will become a powerful analytical tool for portable or on-site analysis

Multi-turn Imaging TOF Mass Spectrometer

“MULTUM-IMG”

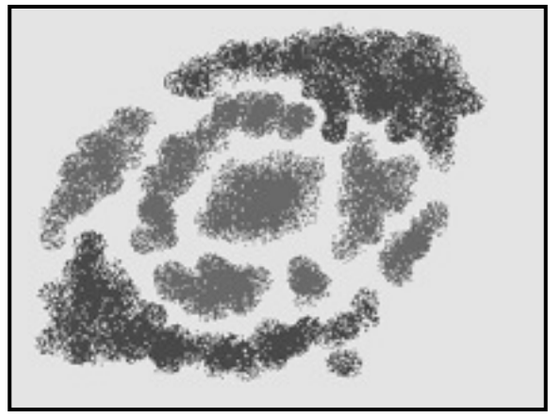
supported by Core Research for Evolutional Science and Technology (CREST), JST

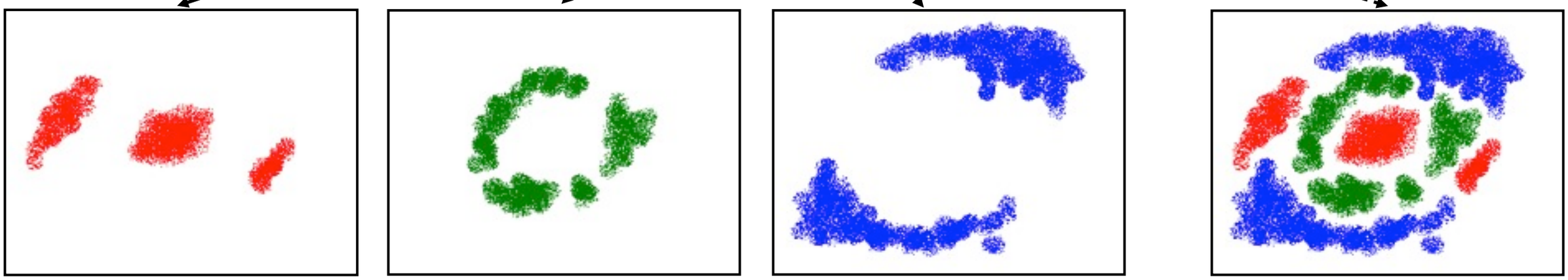
H. Hazama, et.al , *Appl. Surf. Sci*. **255** (2008), 1257.

H. Hazama, et.al , *J. Biomed. Opt.,* **16** (2011), 046007.

What is imaging mass spectrometry ?

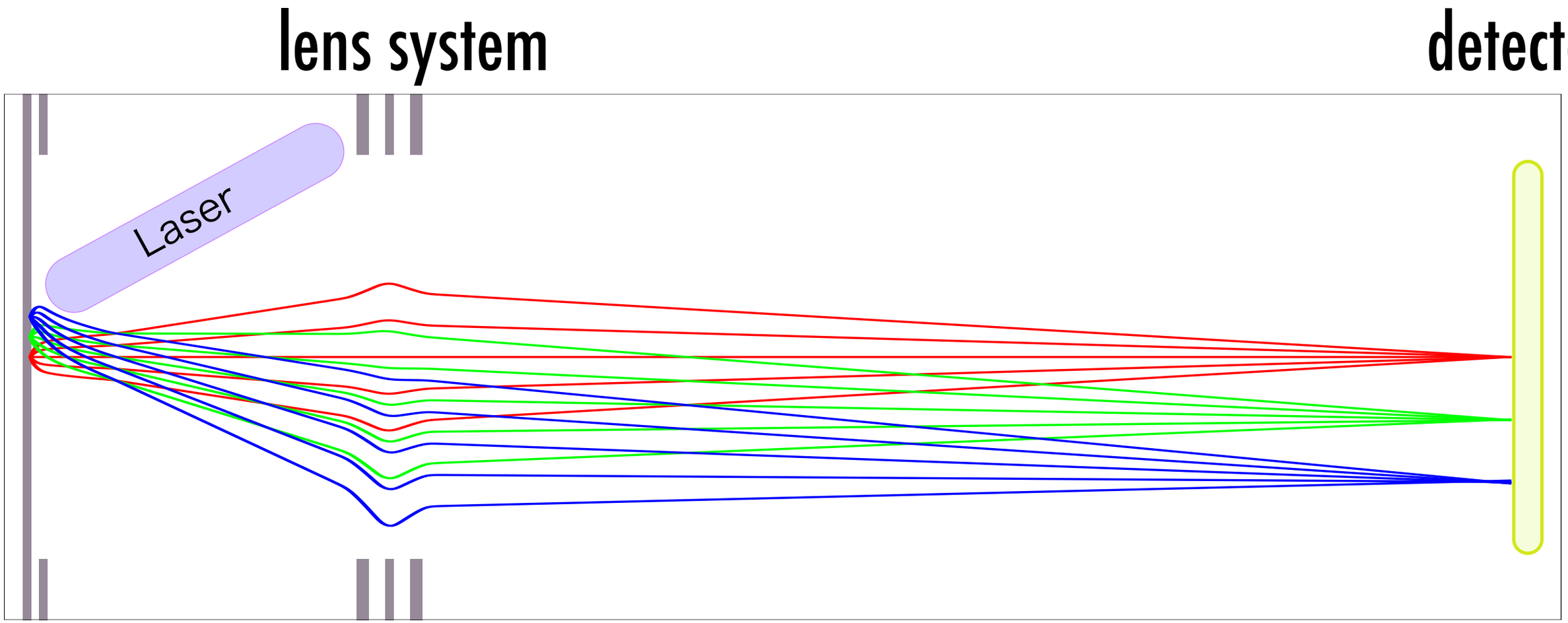
Sample





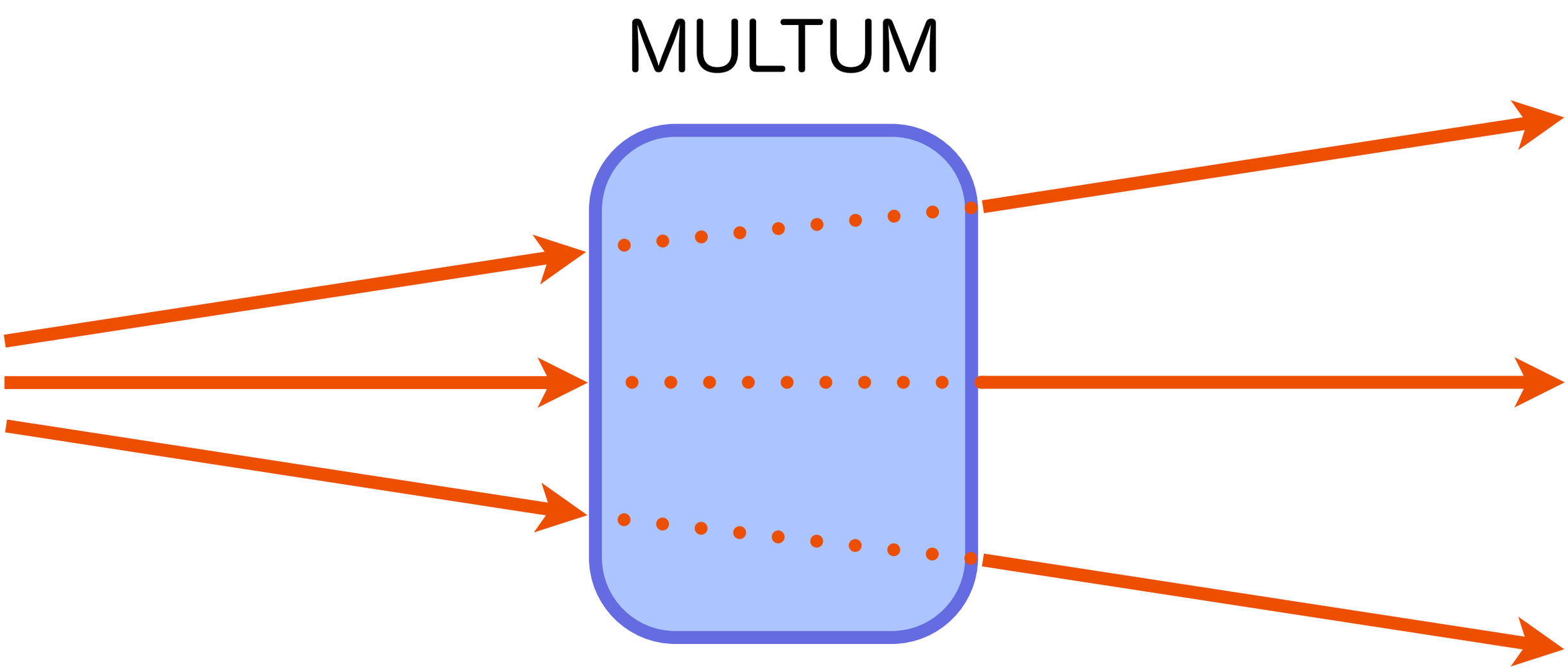
m/z 500 *m/z* 1000 *m/z* 1500 Total

Basic ion optics for stigmatic mass microscope

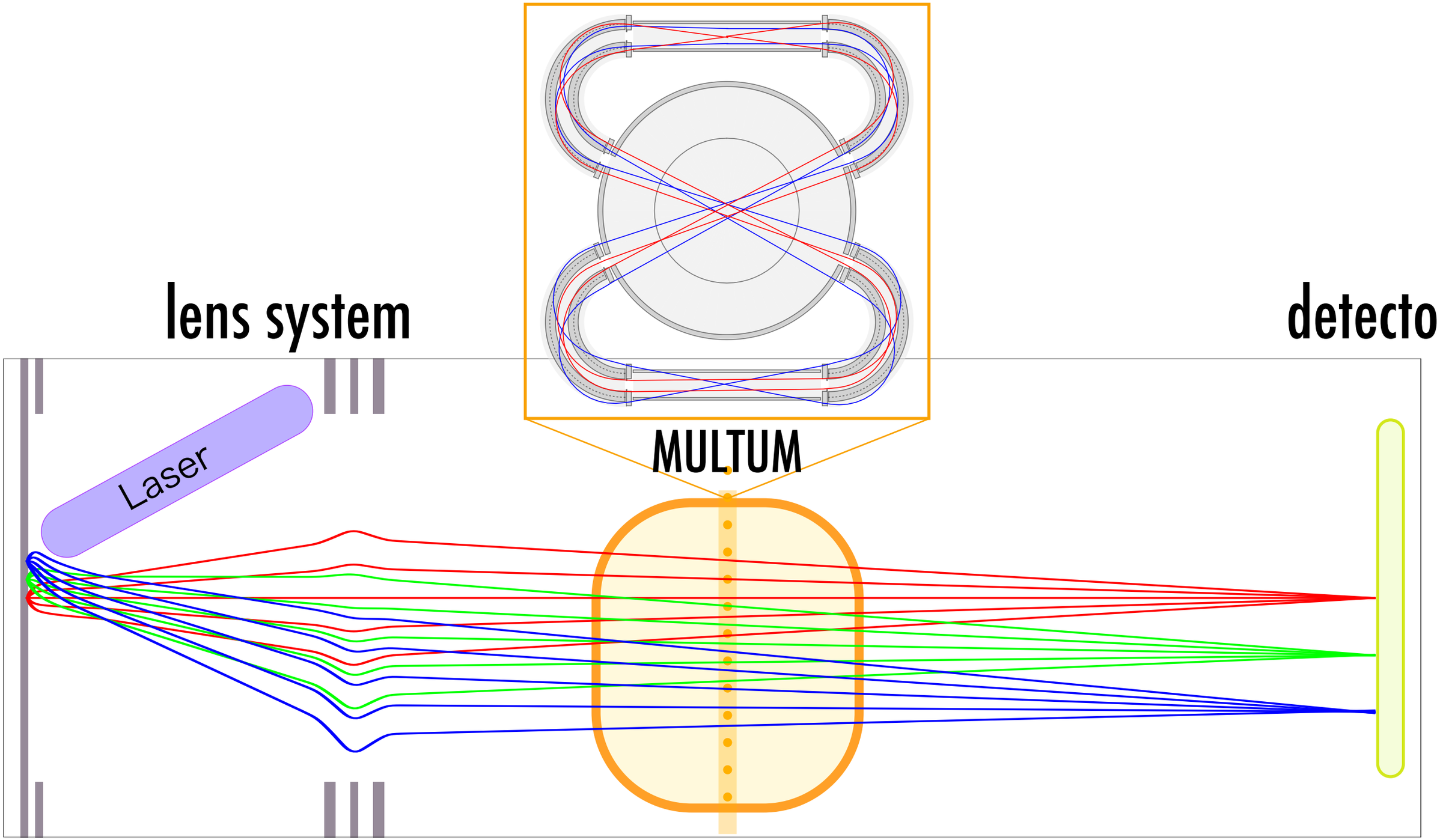


flight pass for time-of-flight measurement

MULTUM's optics



Advanced ion optics for stigmatic mass microscope

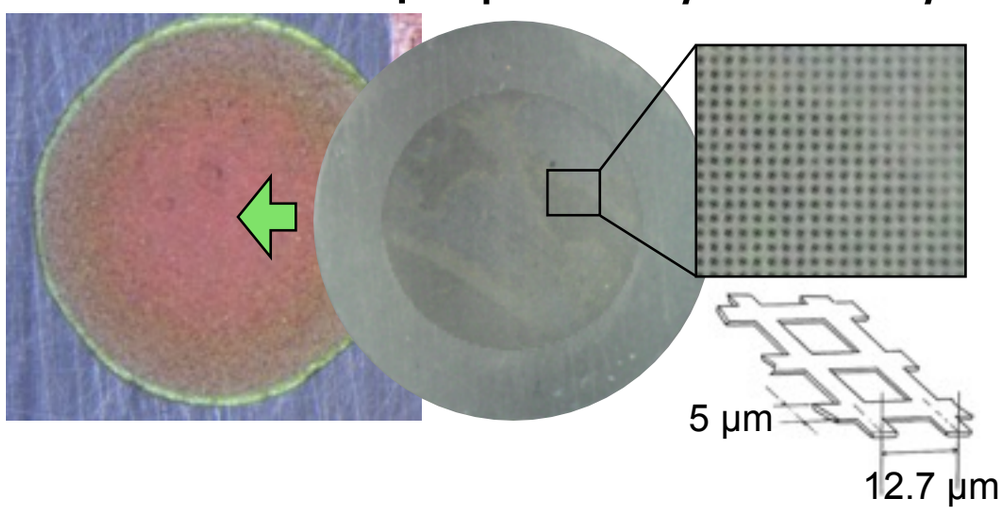


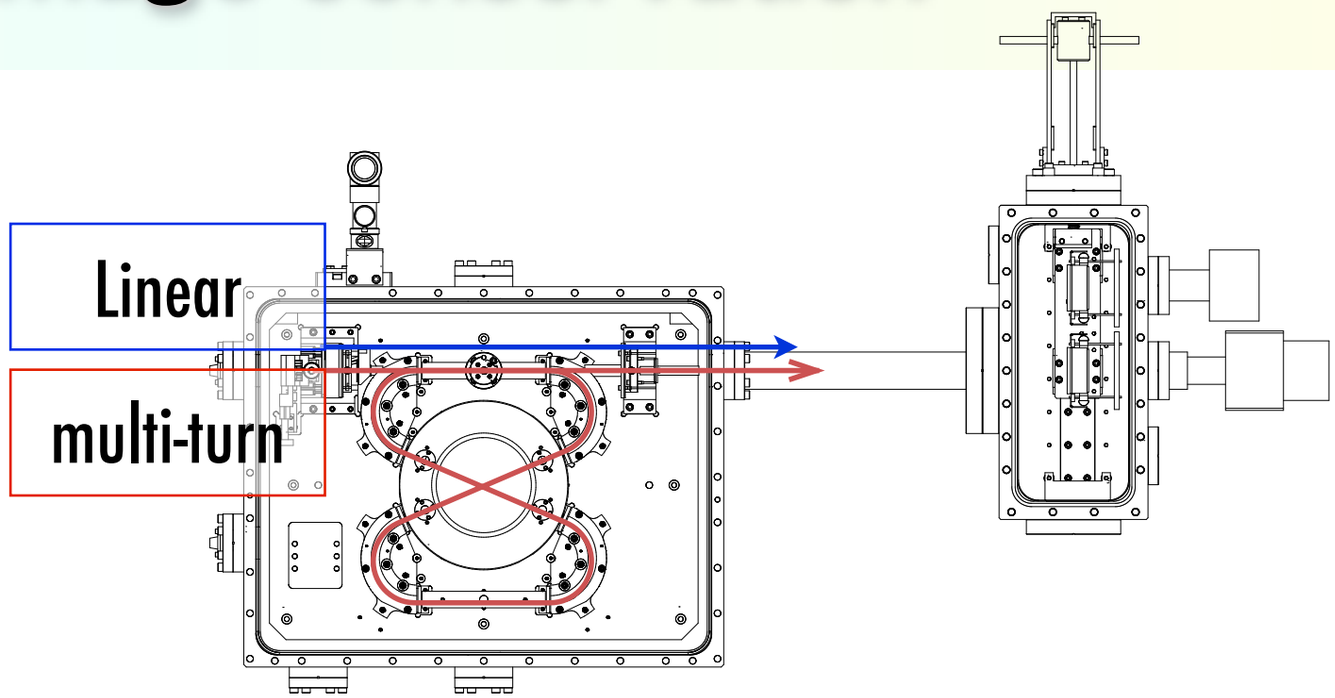
Multi-turn time-of-flight Imaging Mass Spectrometer

MULTUM-IMG2

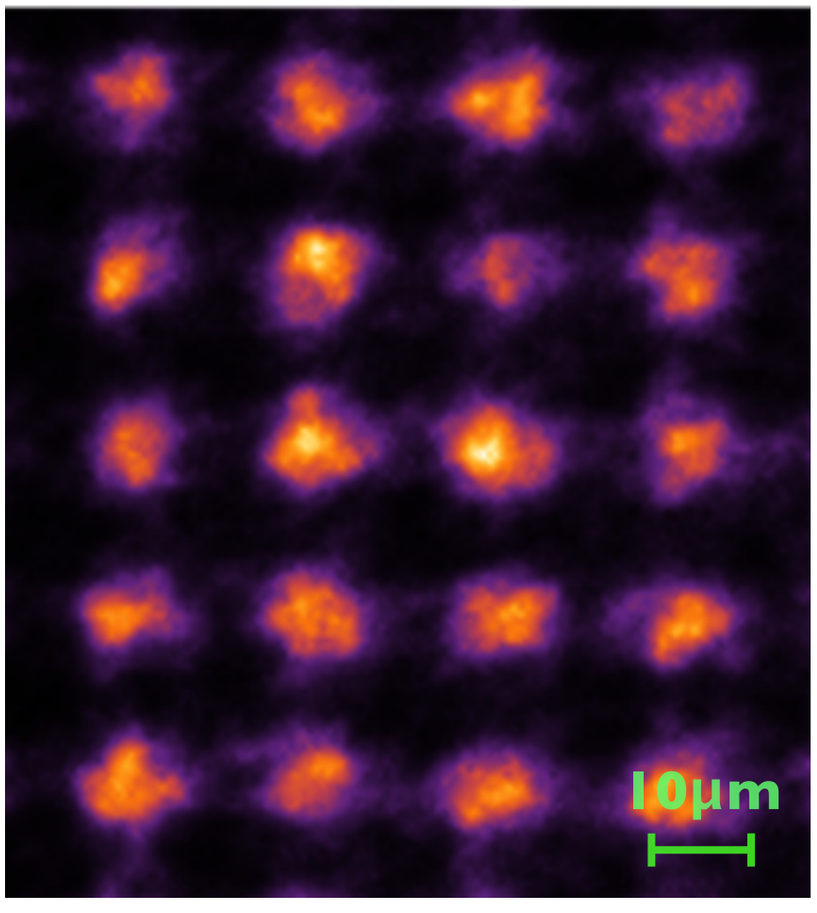
Evaluation for image conservation

metal mesh of 12.7 μm pitch on crystal violet dye

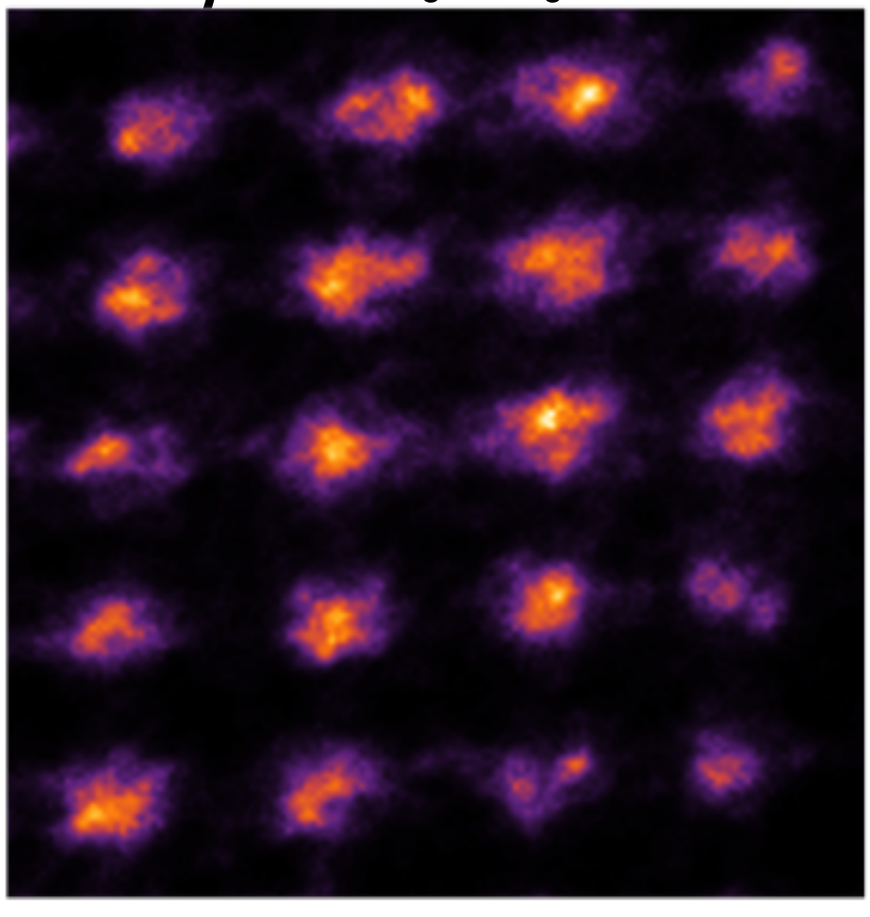




Linear (flight length of 0.8 m)



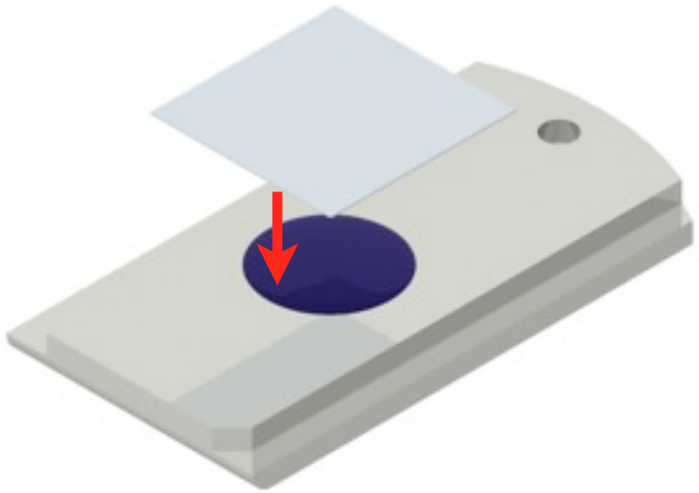
8 cycles (flight length of 11.5 m)



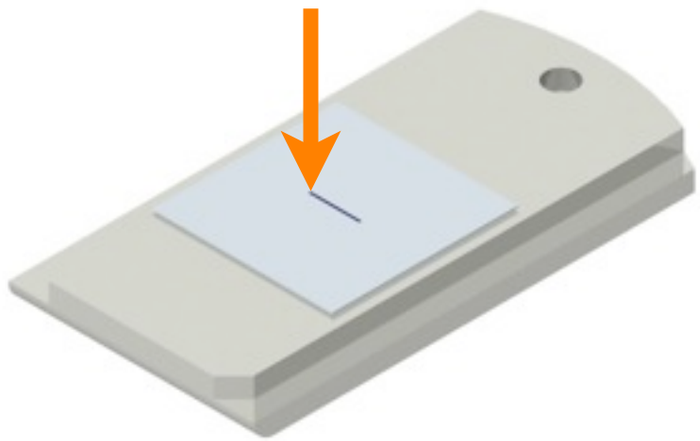
Evaluation for spatial resolution

Making evaluation sample

① A dried droplet of crystal violet dye is covered by thin aluminum foil of 1.5 μm thickness.

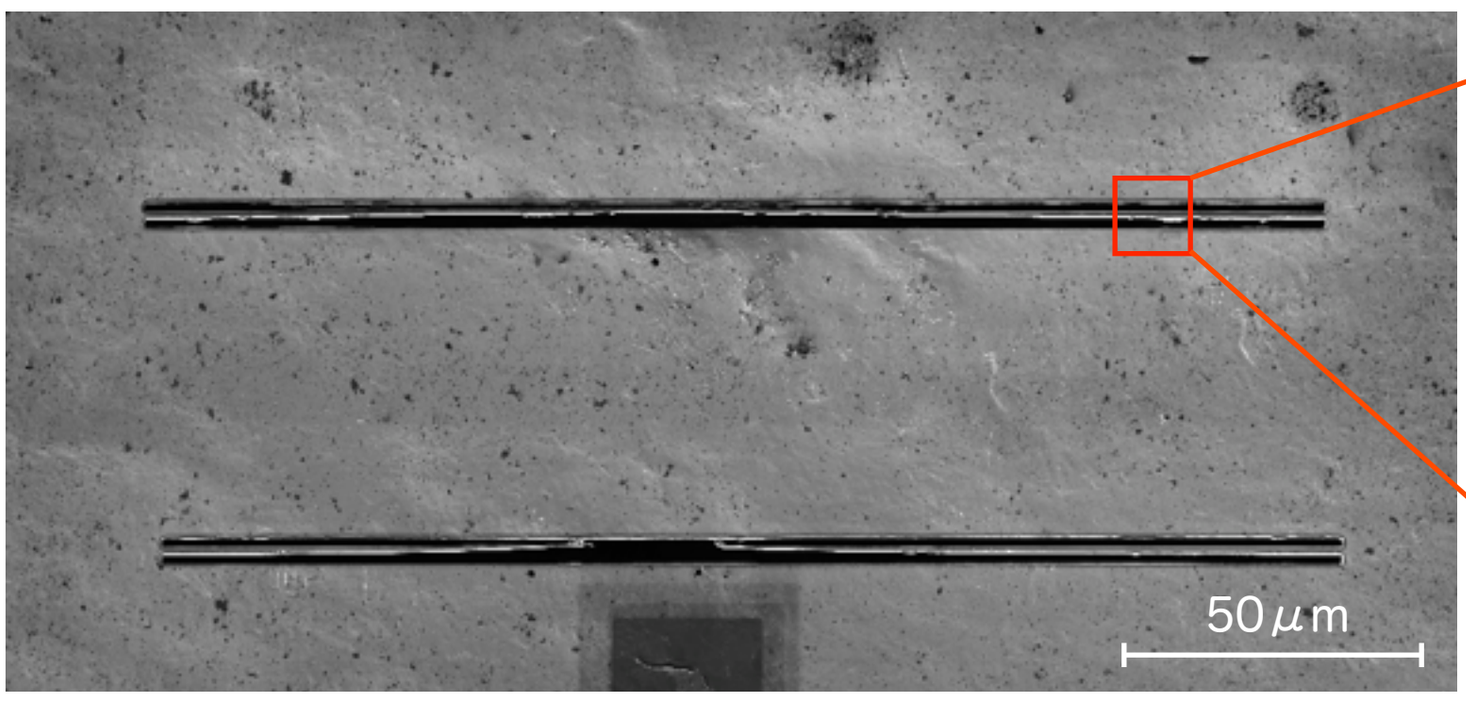


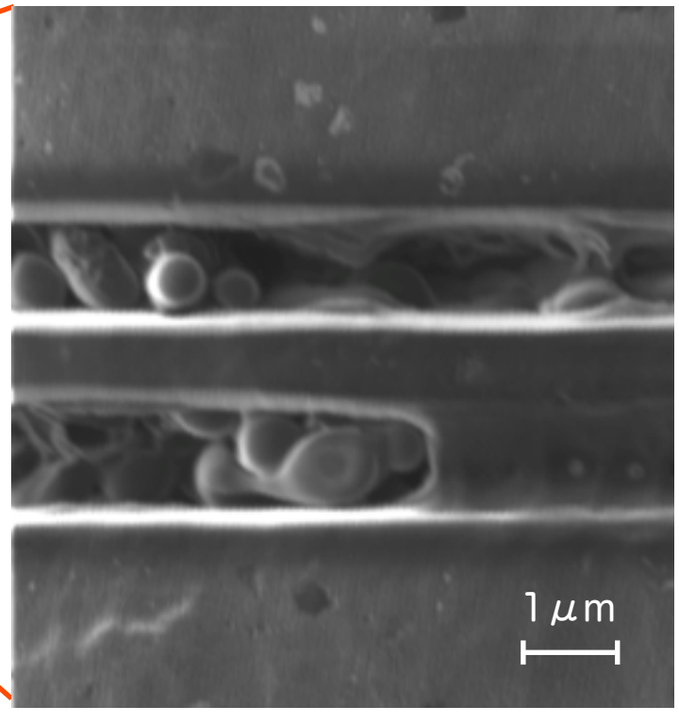
② Etching with focused ion beam to form fine slits



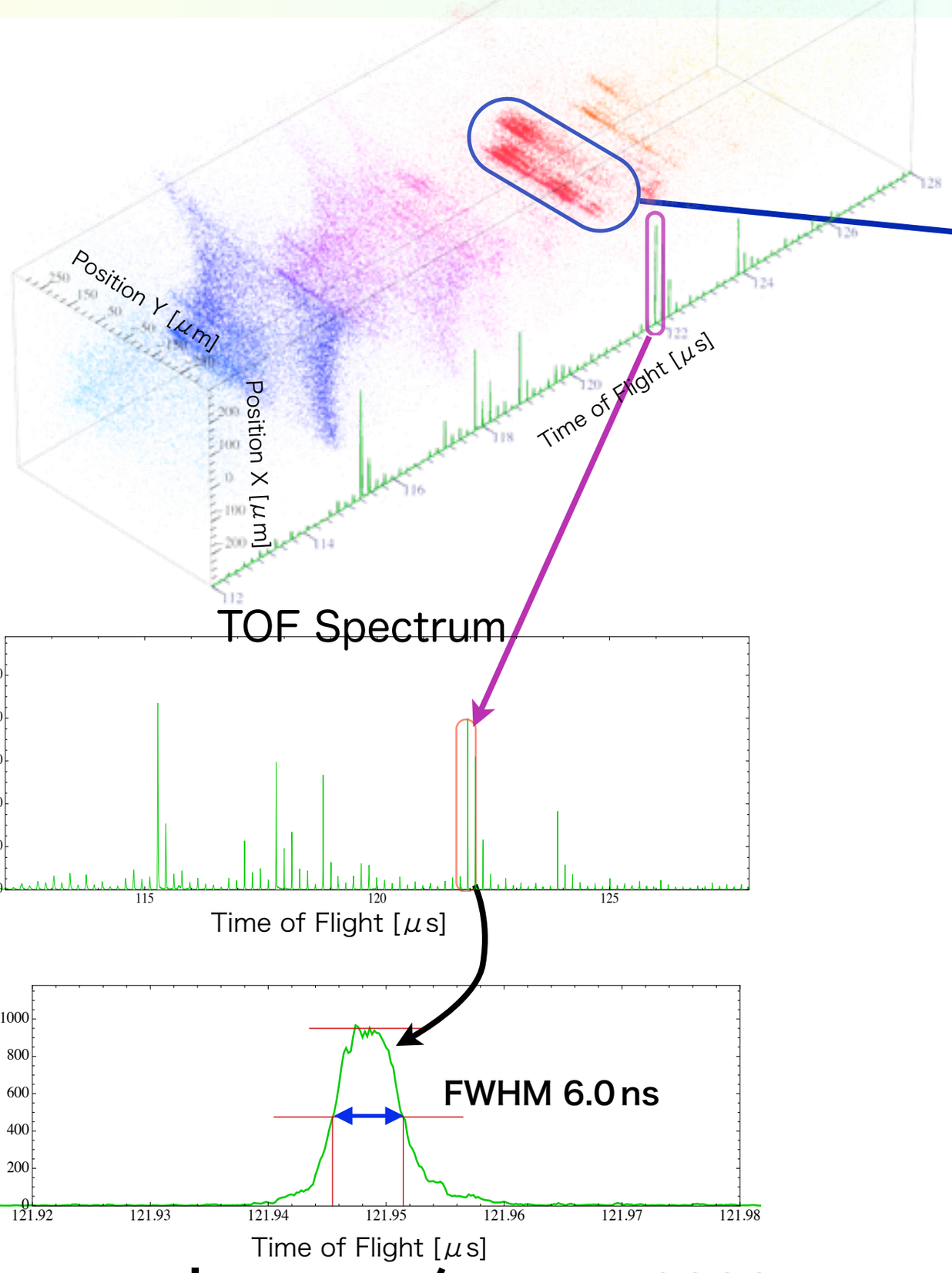
SEM image

Two slits of 1 μm width are aligned with 1 μm gap.

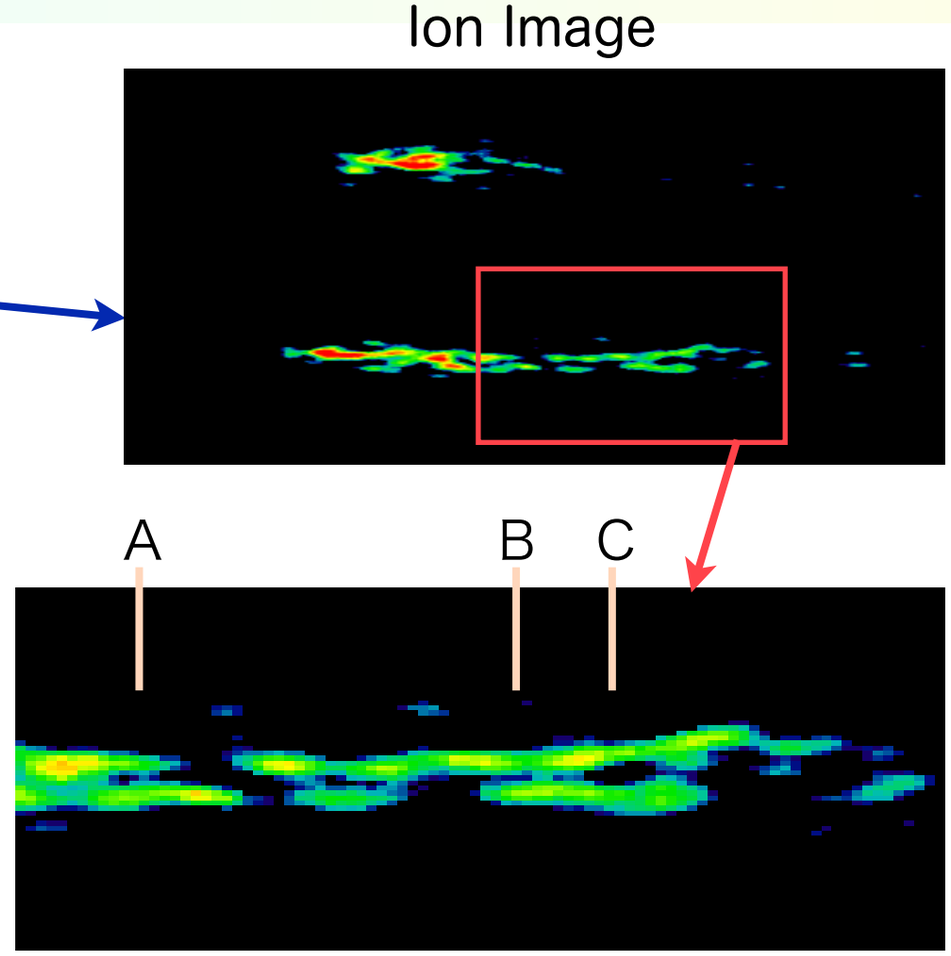


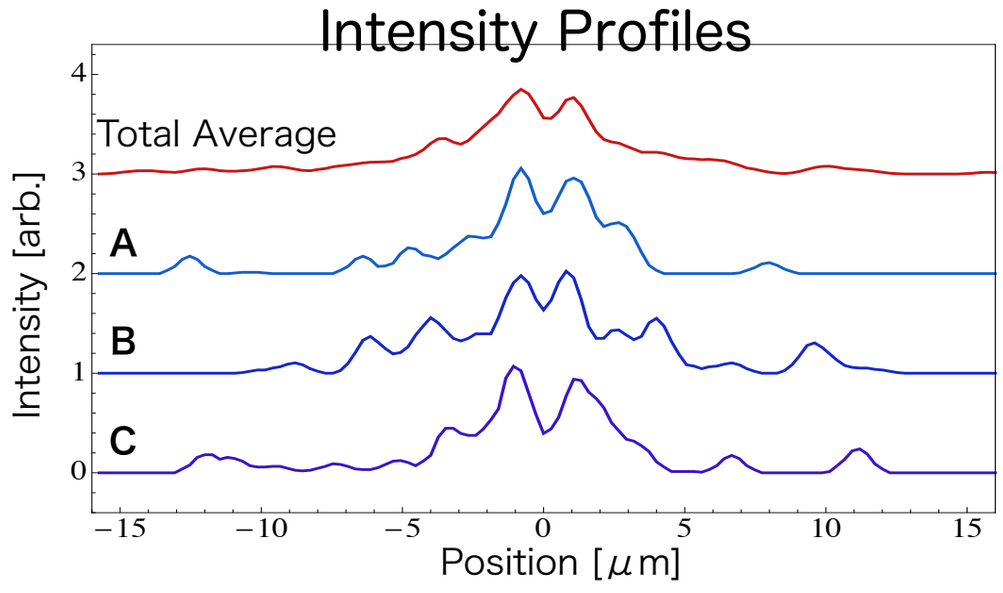


Evaluation for spatial resolution



mass resolution $m/\Delta m$ >10000





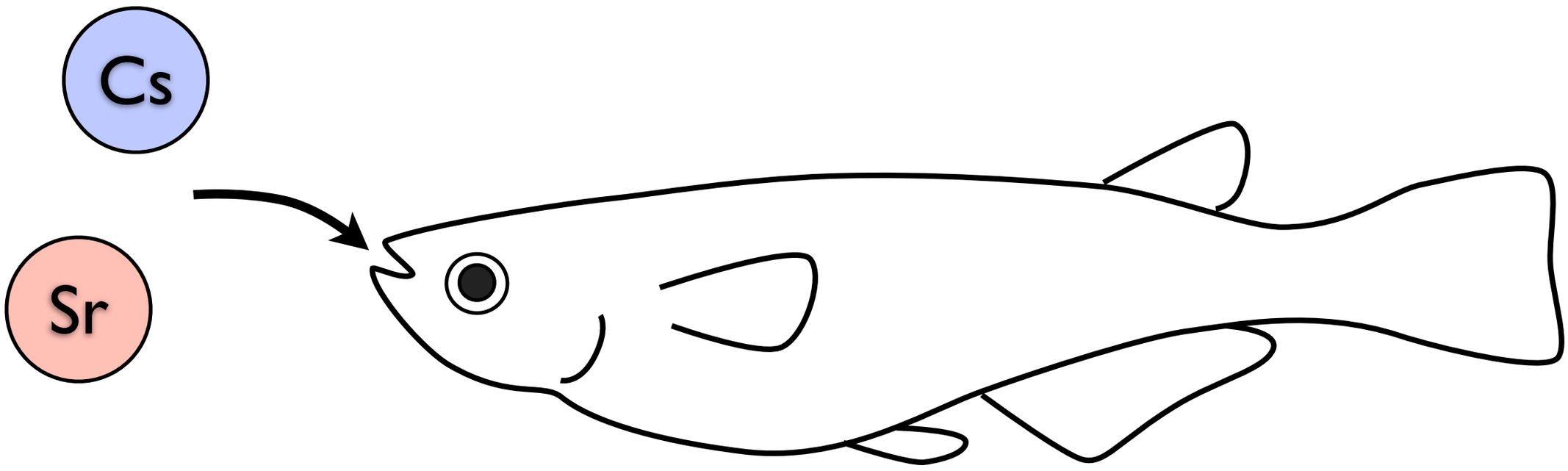
spatial resolution 1μm

Imaging Applications

- Observation of accumulated metal cation in fish

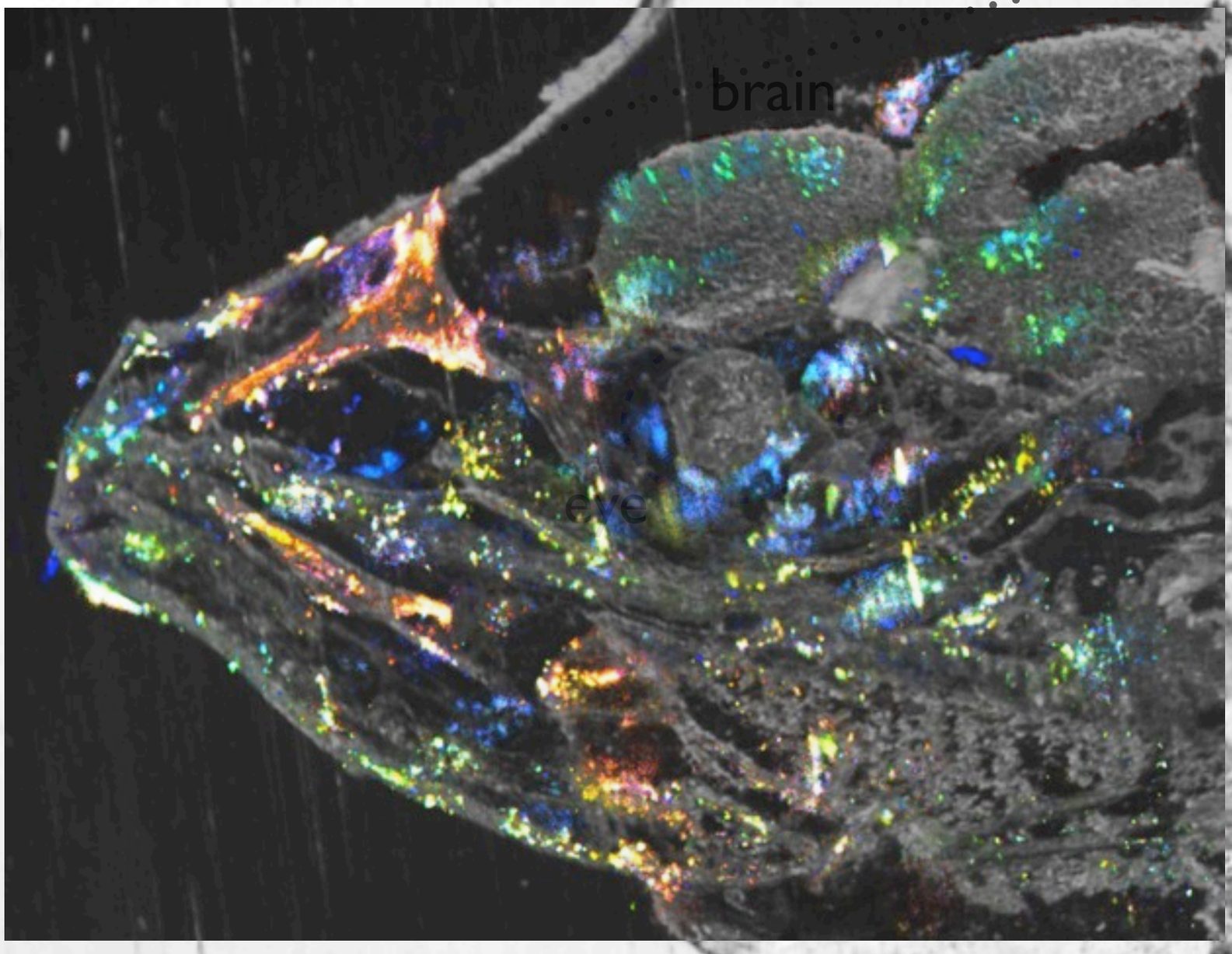
Observation of accumulated metal cation in fish

Small fish (medaka; *Oryzias latipes*) was raised for two weeks in water containing Cs and Sr.



Observation of accumulated metal cation in fish

ion image



R : Na
G : K
B : Cs

1 mm

Conclusion

- We developed multi-turn time of flight mass spectrometer.
- High mass resolving power were achieved with compact size instrument.
- Applications of MULTUM are in progress.