A NON-DESTRUCTIVE PROFILE MONITOR USING A GAS SHEET

–for the J-PARC –

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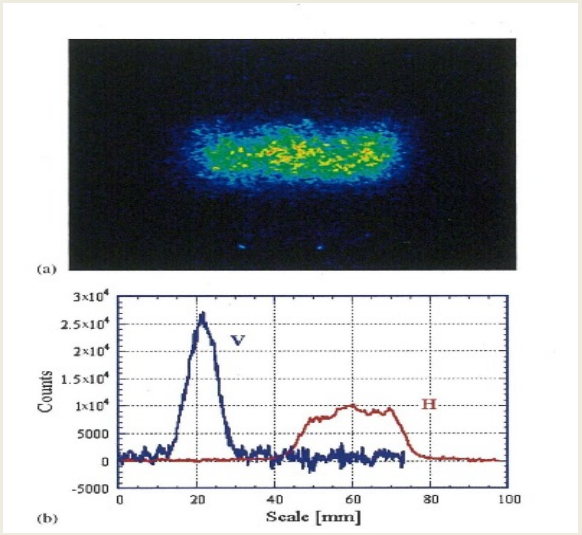
Contents

Introduction *<previous studies>*

Gas target	Method	Developer	Reference
Sodium curtain (1975)	Evaporation by heating Mechanical collimators	B.Vosicki, K.Zankel (CERN)	IEEE Trans., NS-22 (1975) 1475.
Carbon jet (1991)	Laser ablation Mechanical collimators	R.Galiana, D.Manglunki *et al.* (CERN)	Proceedings of 1991 PAC, USA, p. 1198
Magnesium jet (1998)	Evaporation by heating Mechanical collimators	A.V.Bubley, V.I.Kudelainen *et al.* (Russia)	Proceedings of 17th International Conference on High-Energy Accelerators (HEACC 98), p. 357.
O2 gas-sheet (2000~)	Nozzle beam Focusing with magnets	Y.Hashimoto, T.Fujisawa *et al.* (KEK, NIRS)	Nucl. Instr. and Meth. A 527 (2004) 289.

Y. Hashimoto et al. have succeeded to develop O_2 gas-sheet beam profile monitor.



Some difficulties for applying to J-PARC
- gas species (N_2, Xe)
- gas density ($\geq \sim 10^{-3}$ Pa (light detection))
- size ($\geq \phi$ 150 mm)

Introduction

<to generate a gas sheet>

"beaming" effect
—well known in vacuum science & technology

Spatial distribution
of emitted molecules
is modified by
the shape of pipe.

<Example>

orifice: cosine law (blue)

2a=ℓ pipe: beaming (grey)

(length=diameter)

With "beaming" technique, molecules can be forced to concentrate on a plane.

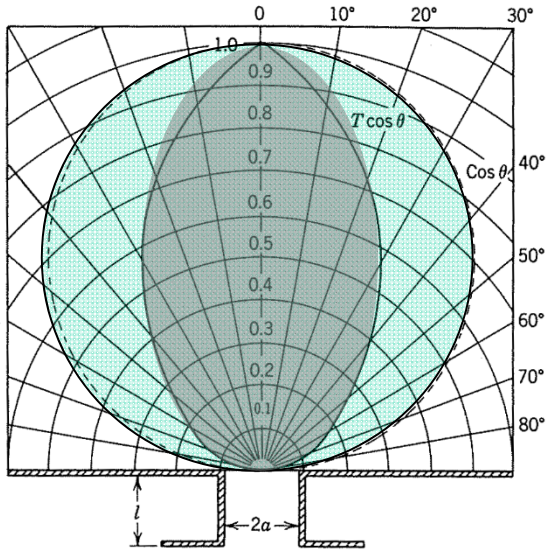
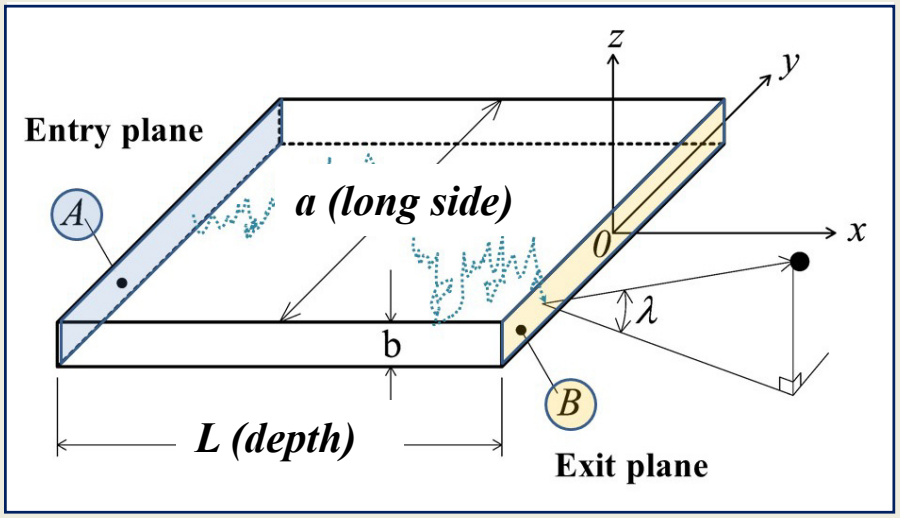


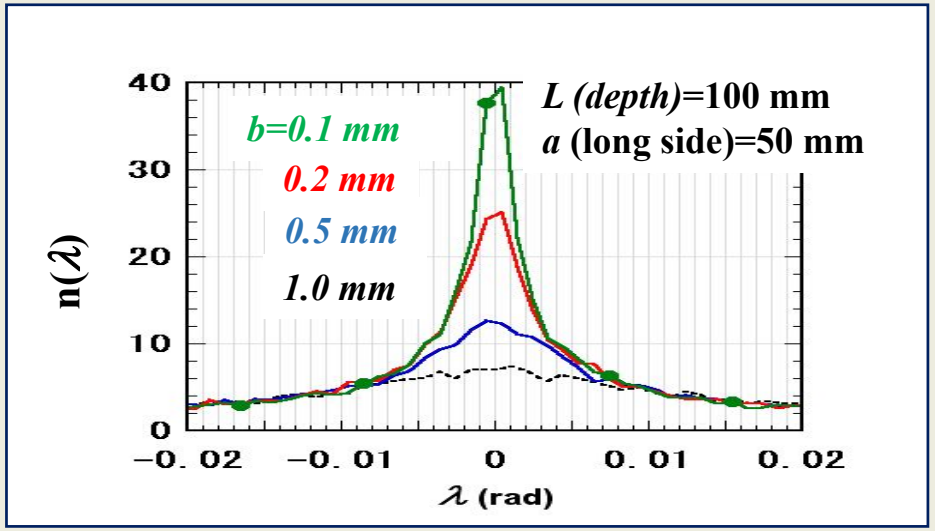
Fig. 4.6. Spatial distribution for free molecule flow through a short tube under conditions where L, the mean free path, is greater than $2a$, the diameter, and $l = 2a$. $T \cos \theta$, the full curve, shows the calculated distribution (T = function of θ), and the dotted curve shows the expected cosine law distribution (Clausing). The significance of the values on the vertical scale is illustrated by the following example: for 40°, $\cos \theta = 0.766$ and $T \cos \theta = 0.4$.

Cited from "Scientific foundations of vacuum technique" (Dushman, Lafferty)

Development of gas sheet generator
2.1 Monte Carlo simulations

<deep slit>

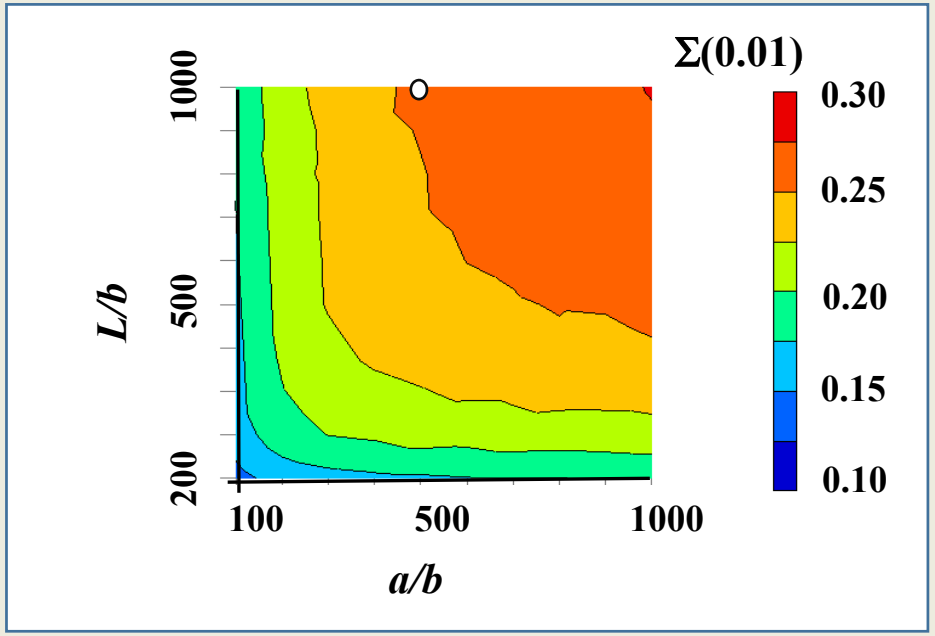




n(λ): angular distribution function

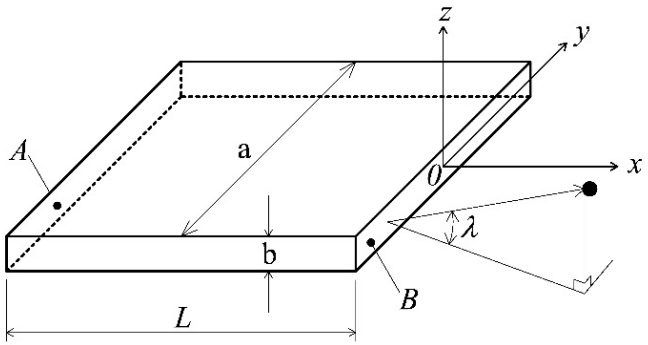
$$\Sigma(0.01) \equiv \int_{-0.01}^{0.01} n(\lambda) d\lambda$$

If ***L/b* >>1 and *a/b* >>1**, slit is effectual to make a gas sheet.

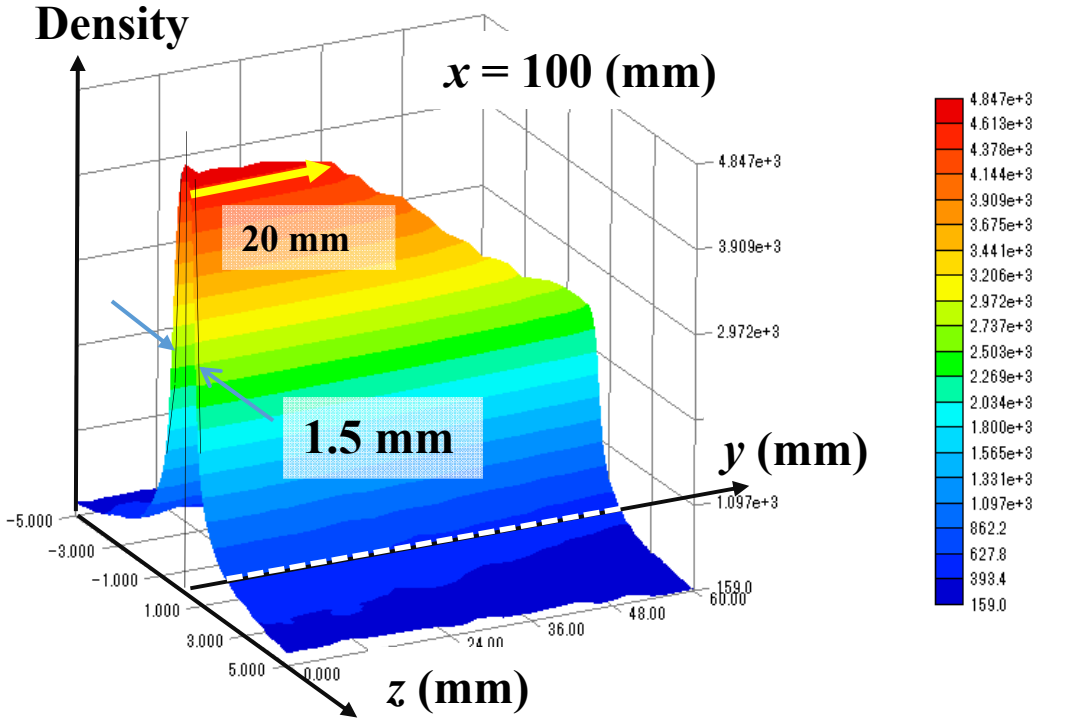


Development of gas sheet generator
2.1 Monte Carlo simulations

Anticipated performance of the gas sheet generator for demo exp.

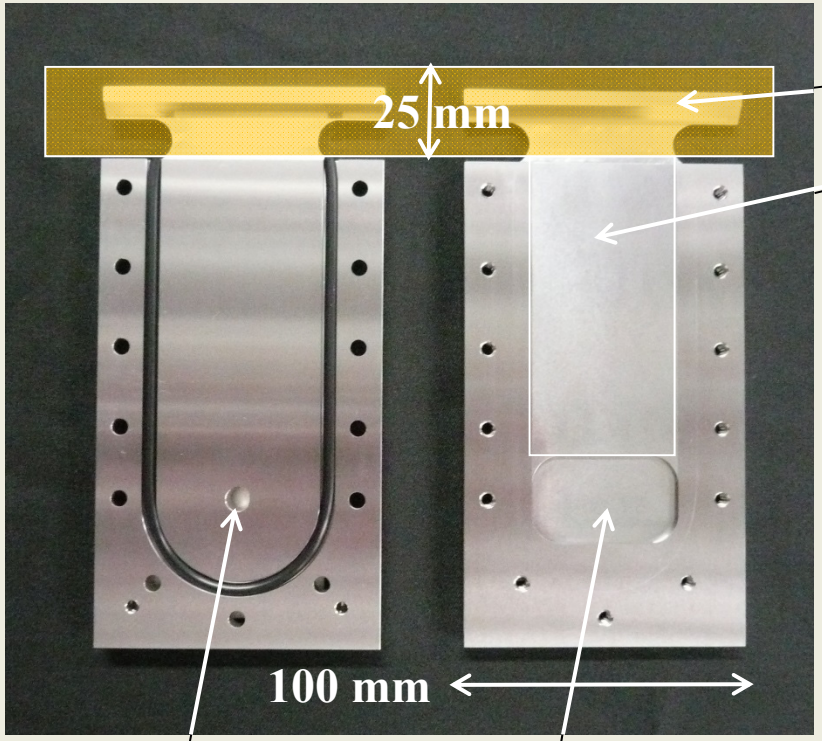


Design values
a = 50 mm
b= 0.1 mm
L = 100 mm



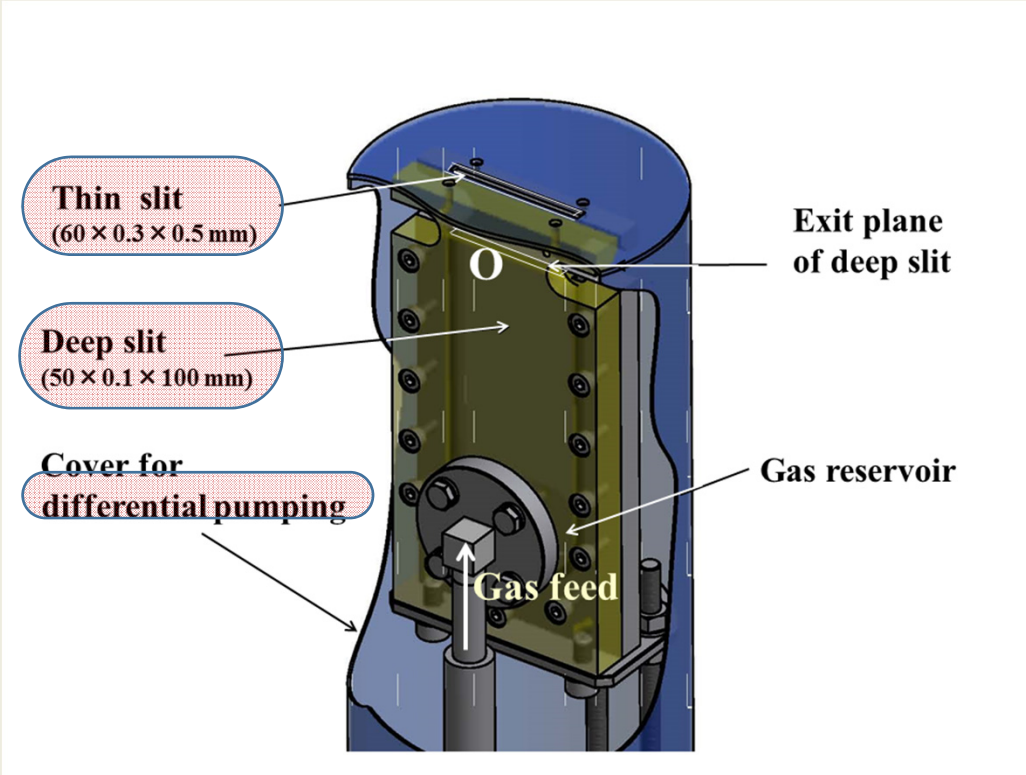
2.2 Gas sheet generator for demonstration experiments

<structure>



Support for the cover (on the cover)

Pit for the deep slit (50 × 0.1 × 100 mm)

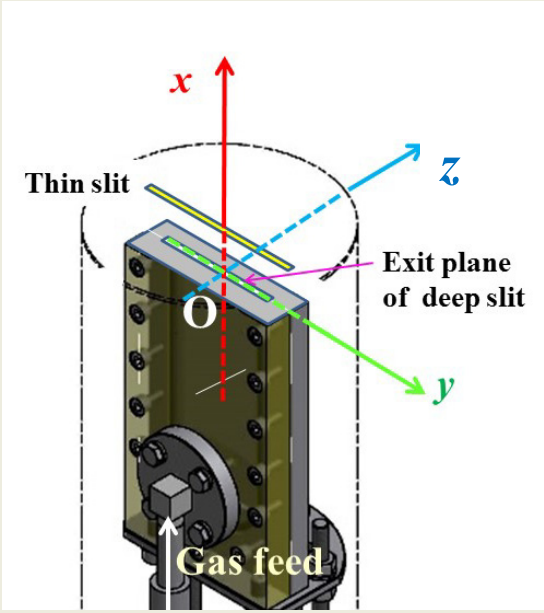


Deep slit is formed between 2 SUS304 plates.

Main parts;(1) deep slit (2)thin slit and (3)differential pumping

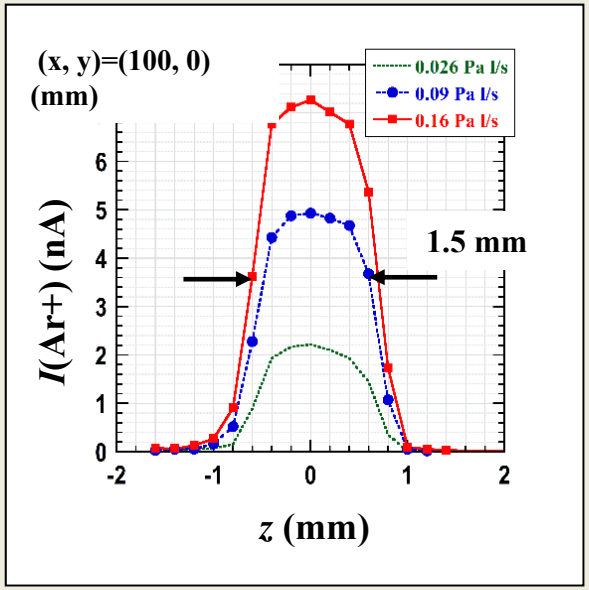
2.2 Gas sheet generator for demonstration experiments

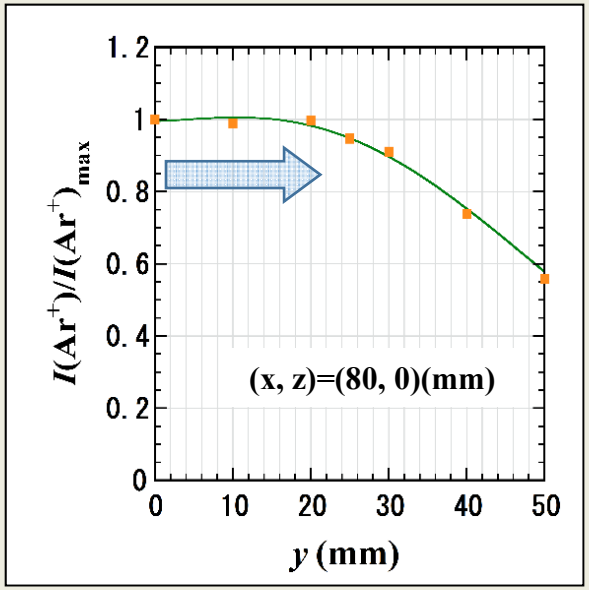
<performance>

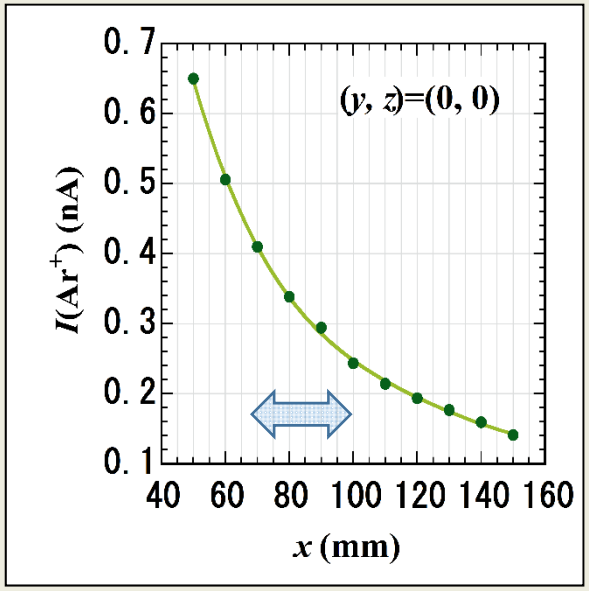


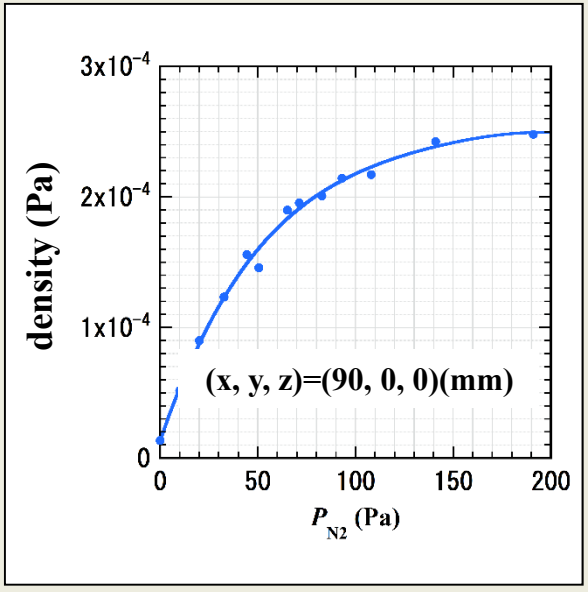
O : center of exit plane of deep slit

Gas sheet
(1) thickness :1.5 mm
(2) density : ≥10-4 Pa (at x=100 mm)
(3) -20 ≤ y ≤ 20
uniform density (y direction)





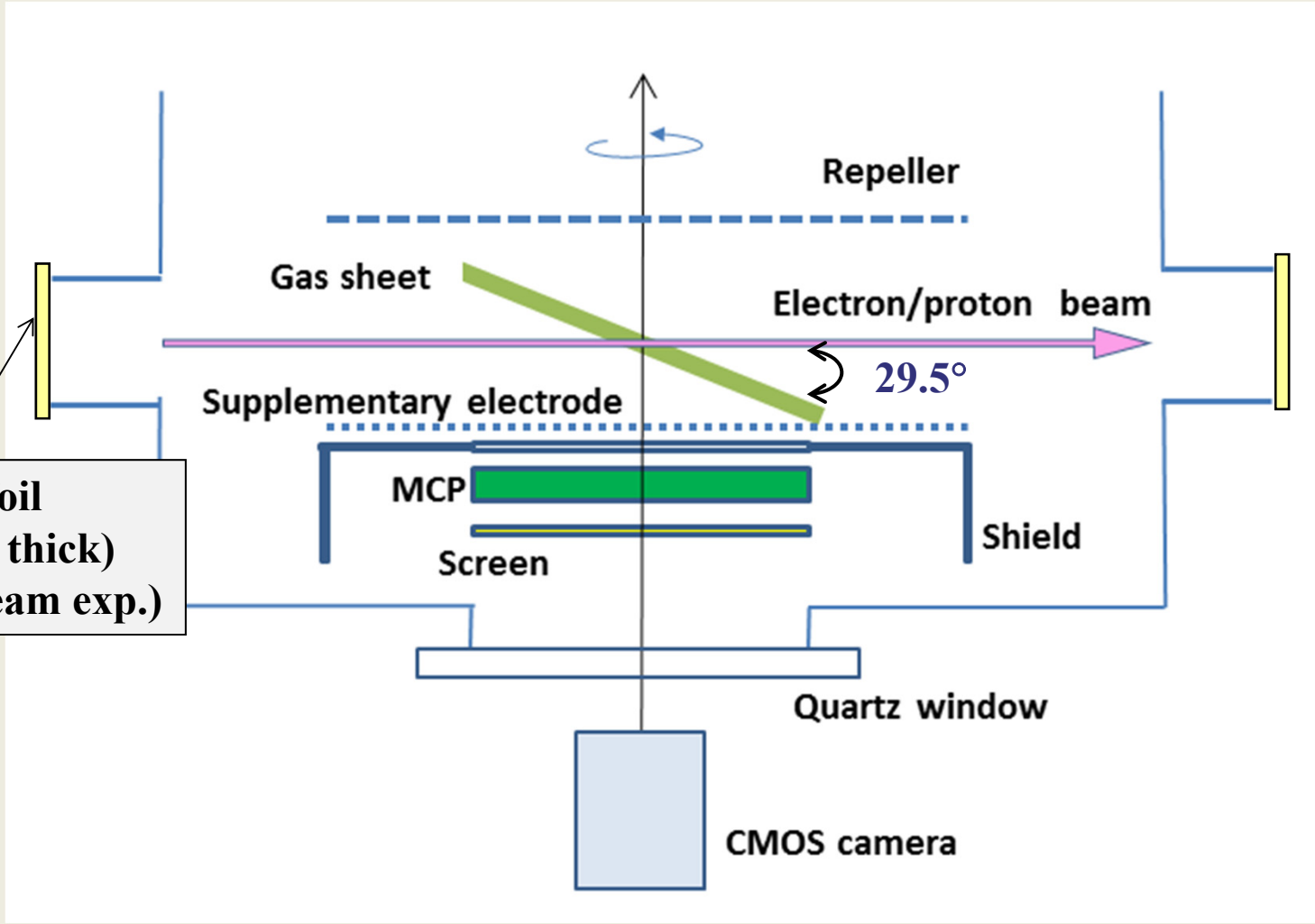




Demonstration experiments

3.1 Experimental layout

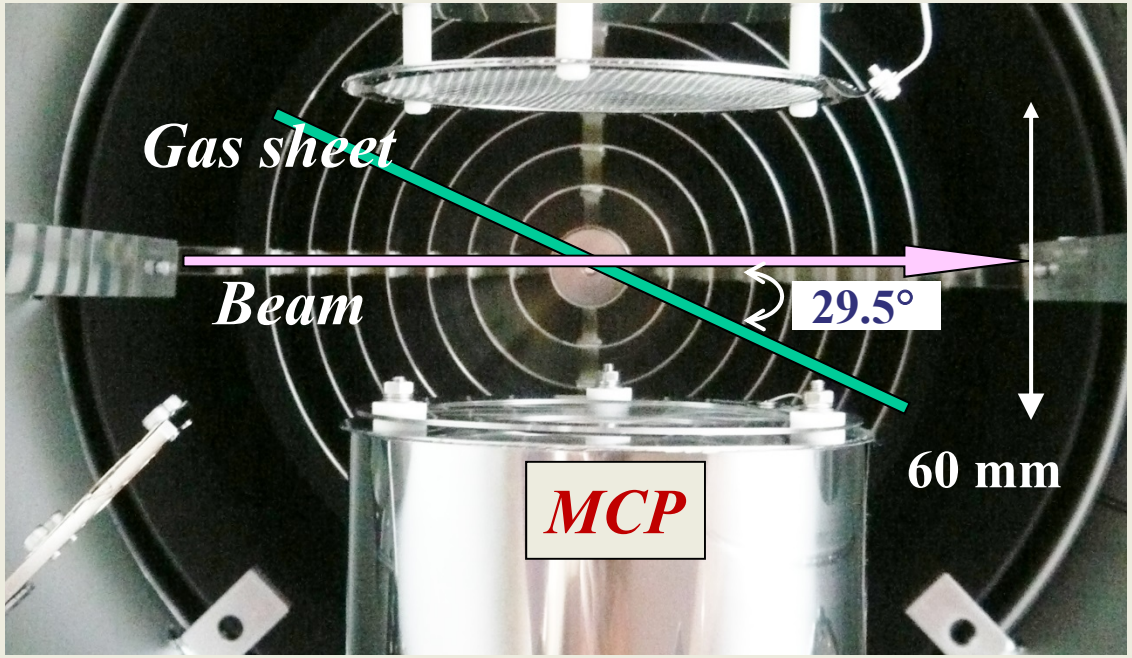
<detection system>



C foil
(25 μm thick)
(for H^+ beam exp.)

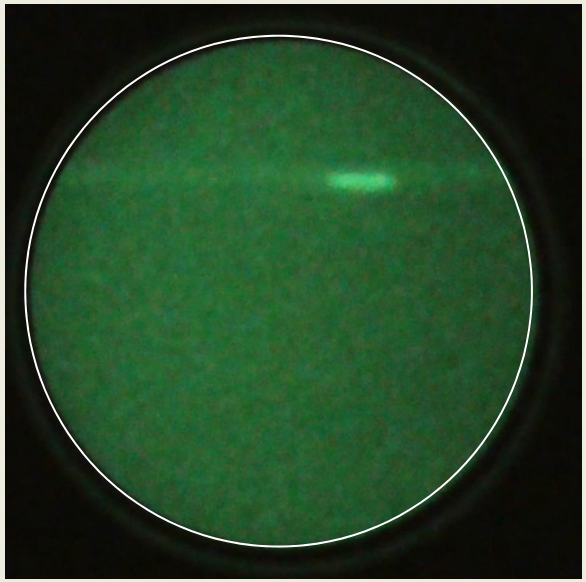
Demonstration experiments
3.1 Experimental layout

<detection system>



3.2 Electron beam detection

<general view>



Bright spot is long laterally
because the gas sheet
and the beam cross each other
with 29.5°.
From the breadth,
gas-sheet thickness is estimated
to be 1.5 mm.

30 keV electron beam
I = 6 μA
Diameter = 0.35 mm (measured by cut-off plate)

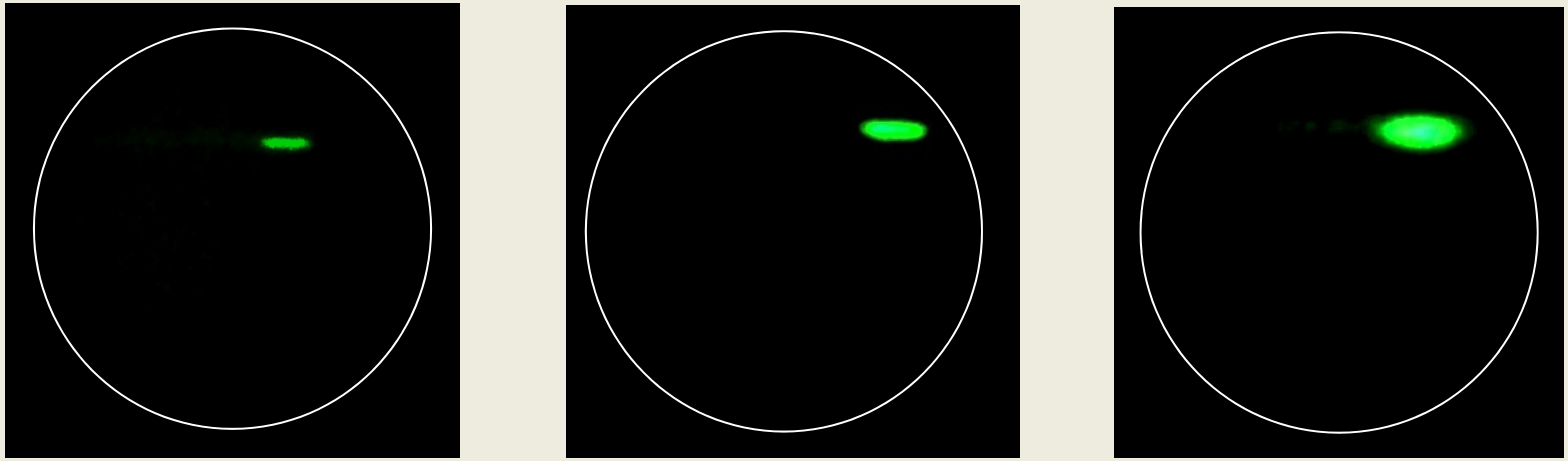
Gas-sheet density=8×10^{-5} Pa
Ambient pressure=8×10^{-6} Pa

Bright spot:
ions generated by the collision of the beam with gas sheet

Thin belt-like trace:
ions generated by the collision of the beam with uniformly distributed ambient gas

3.2 Electron beam detection

<profile observation>



< in focus ← e-beam → out of focus >
(0.35 mmϕ ~2 mmϕ)

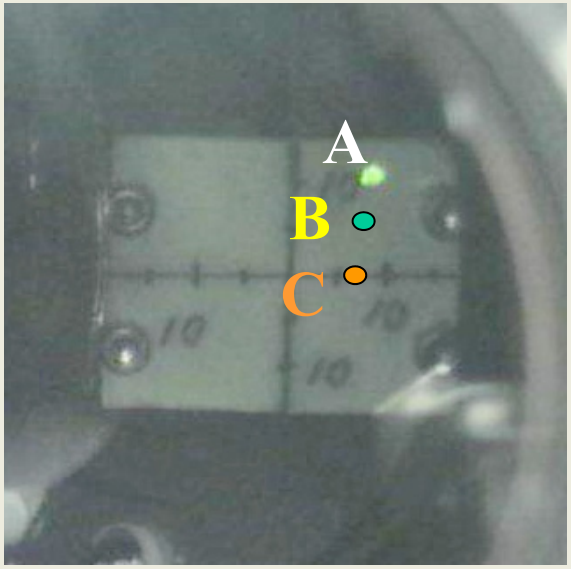
Change in the beam profiles are clearly observed, although not quantitatively.

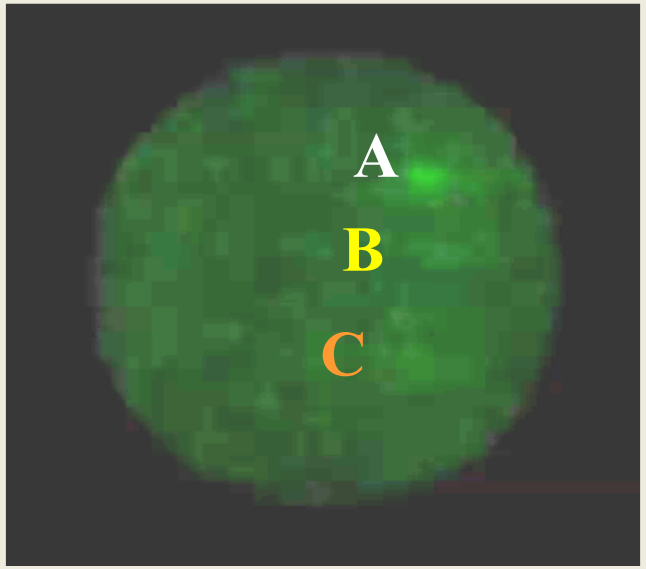
3.3 Proton beam detection

<position monitor>

392 MeV protn beam
I : 300 nA ~ 1 μA
Diameter = 2 mm (measured by fluorescent screen)

C foils (25 μm thick): to improve vacuum condition
↓
rather high background noise





3.3 Proton beam detection

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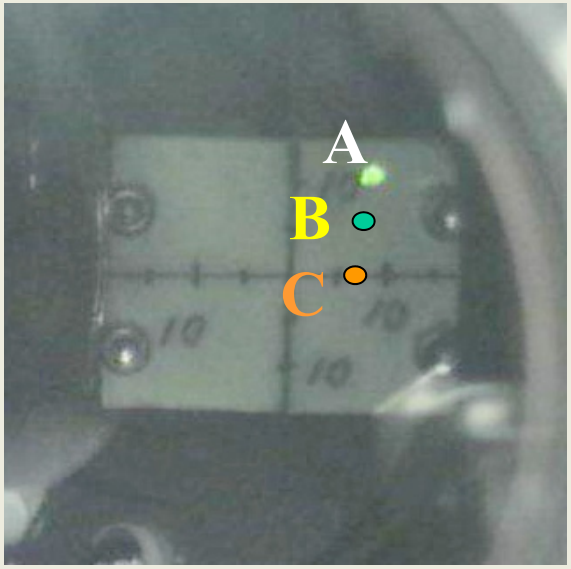
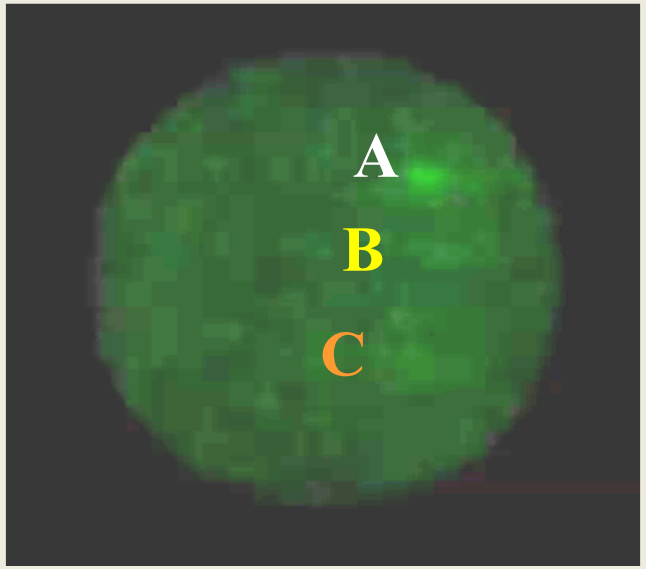




Beam positions are well monitored by the gas sheet monitor.

Summary

1. New type of gas sheet generator

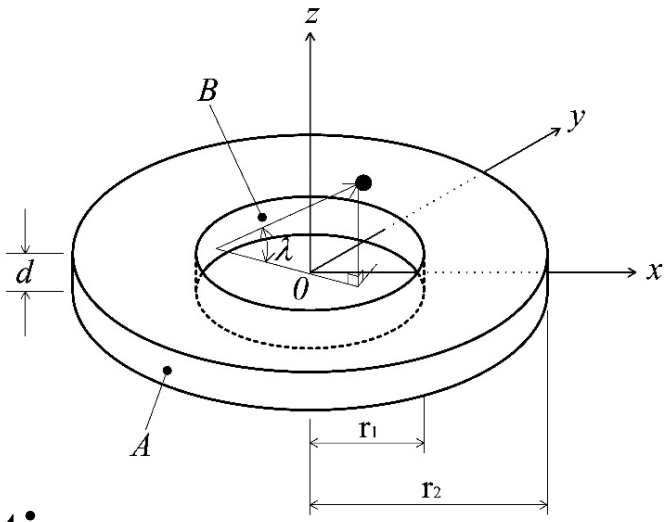
- Concept
- Simulation

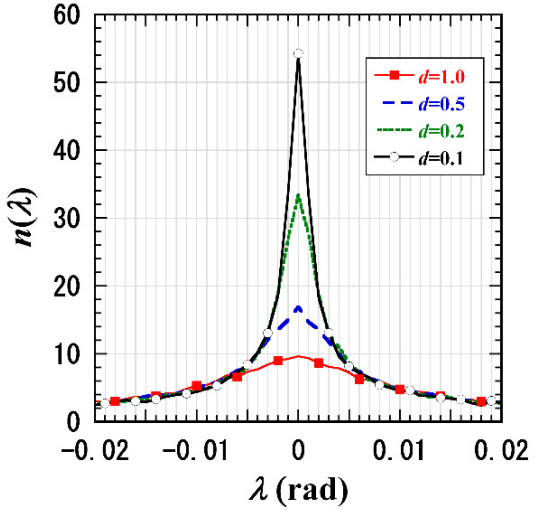
2. Gas sheet generator for demonstration exp.

- Structure
- Performance

3. Demonstration experiments

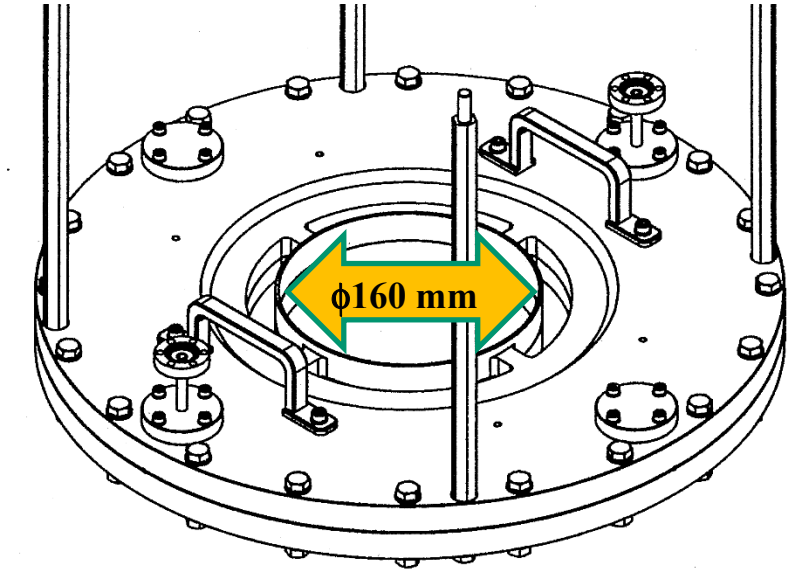
- Electron beam detection
- Proton beam detection



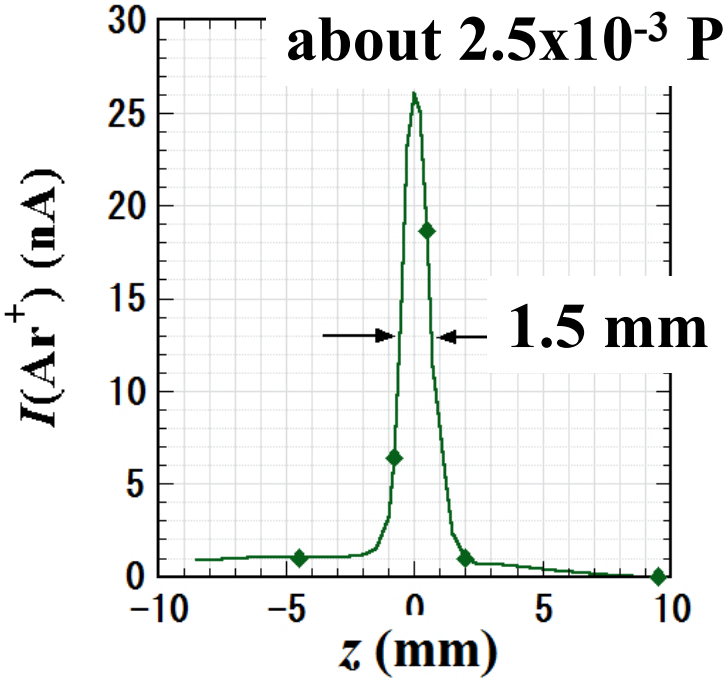


simulation

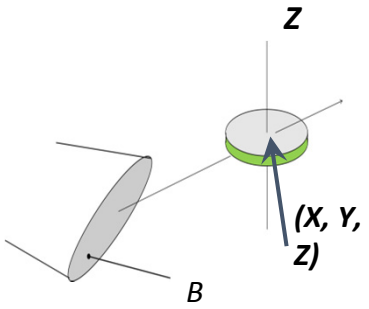
prototype



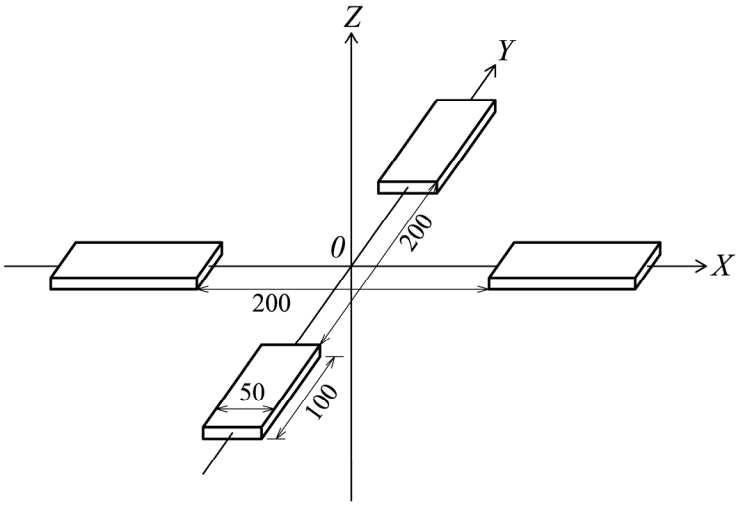
about 2.5x10^{-3} Pa

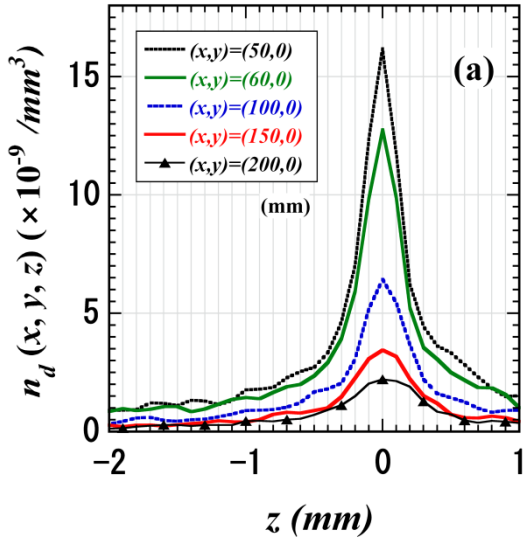


Test-particle Monte Carlo simulation —*the uniform density*—



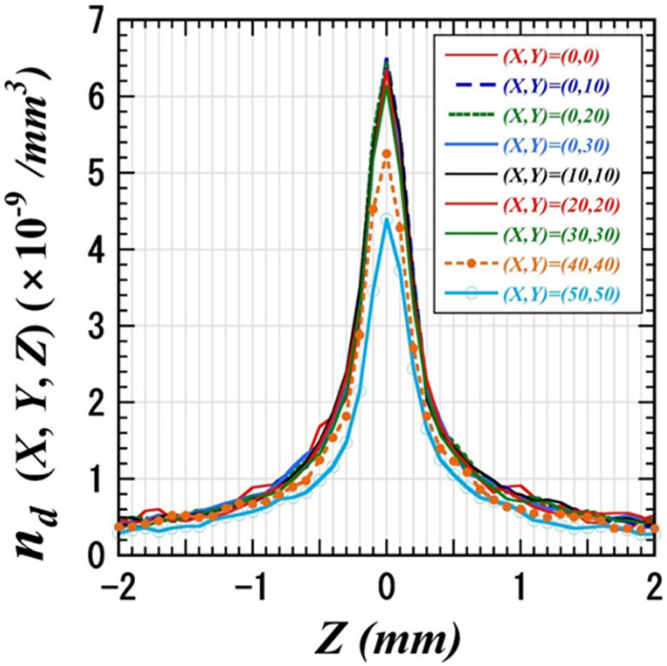
N_i : molecules through the thin cylinder per second
N_0 : total emitted molecules per second
$d(x,y,z) \equiv N_i/N_0 \times \tau/V$
(τ:mean residence time, V:volume of the cylinder)





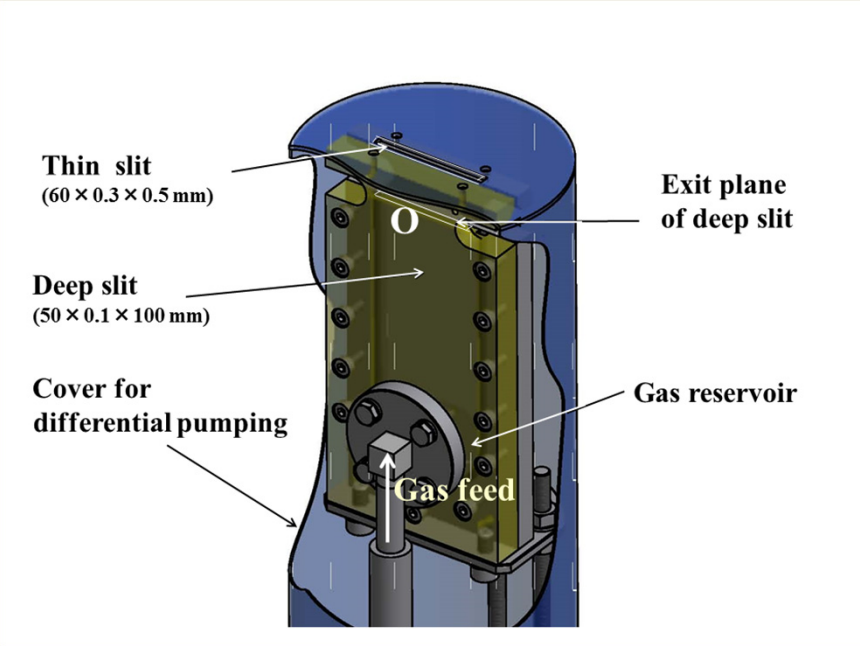
1 rectangular slit

—exit から遠ざかると密度は減少する。



4 rectangular slits

— 均一な密度の
gas sheet が形成される。
左例 ; 90mmϕ


Thin slit
(60 × 0.3 × 0.5 mm)
O
Exit plane
of deep slit
Deep slit
(50 × 0.1 × 100 mm)
Cover for
differential pumping
Gas reservoir
Gas feed