A NON-DESTRUCTIVE PROFILE MONITOR USING A GAS SHEET

—for the J-PARC—

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Introduction

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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    (≥ $\sim$10$^{-3}$ Pa (light detection))
- size           (≥ φ 150 mm)
Introduction

"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.

Cited from "Scientific foundations of vacuum technique" (Dushman, Lafferty)
Development of gas sheet generator

2.1 Monte Carlo simulations

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

If \( L/b \gg 1 \) and \( a/b \gg 1 \), 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
\[ a = 50 \text{ mm} \]
\[ b = 0.1 \text{ mm} \]
\[ L = 100 \text{ mm} \]
2.2 Gas sheet generator for demonstration experiments

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

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

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

< detection system >
Demonstration experiments
3.1 Experimental layout

Gas sheet
Beam
MCP

< detection system >

Gas sheet generator
3.2 Electron beam detection

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

Gas-sheet density = $8 \times 10^{-5}$ Pa
Ambient pressure = $8 \times 10^{-6}$ 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

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.
3.2 Electron beam detection

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

392 MeV proton 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} \text{ Pa}

1.5 \text{ mm}

$\phi 160 \text{ mm}$
**Test-particle Monte Carlo simulation — the uniform density —**

\[ N_i : \text{molecules through the thin cylinder per second} \]
\[ N_0 : \text{total emitted molecules per second} \]
\[ d(x,y,z) \equiv \frac{N_i}{N_0} \times \frac{\tau V}{\nu} \]

(\(\tau\): mean residence time, \(V\): volume of the cylinder)

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1 rectangular slit ー exit から遠ざかると密度は減少する。

4 rectangular slits ー 均一な密度の gas sheet が形成される。

左例: 90mm φ
Thin slit (60 × 0.3 × 0.5 mm)

Deep slit (50 × 0.1 × 100 mm)

Cover for differential pumping

Exit plane of deep slit

Gas reservoir

Gas feed