



Non-destructive Beam Spatial Profile Measurement Using a Gas Sheet Monitor for a High-intensity Ion Beam

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Introduction

Japan Proton Accelerator Research Complex (J-PARC)

= an *intensity-frontier* hadron accelerator (1 MW)
=> Destructive monitor causes radio-activations or breaks of itself

Non-destructive beam profile monitor

Developing Gas Sheet Monitor (GSM) based on beam-gas interaction
=> We have already demonstrated that GSM can measure beam profile

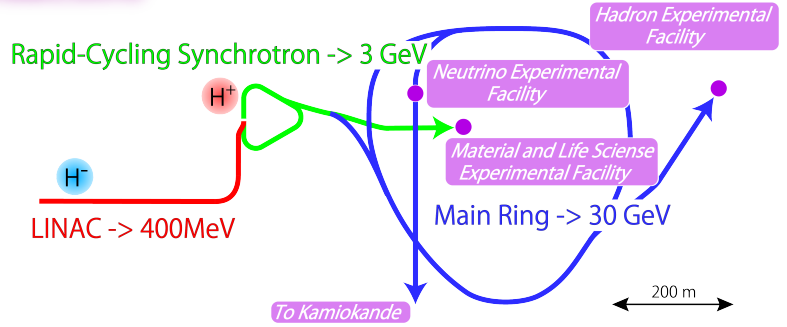
➔ **Objective: demonstration of time evolution study with GSM**

Beam loading effect

RF cavity accelerates beam
=> Beam induces an electric field on cavity wall
=> Electric field for acceleration is weakend, and beam becomes unstable
=> Feed-back/feed-forward control systems compensate the effect

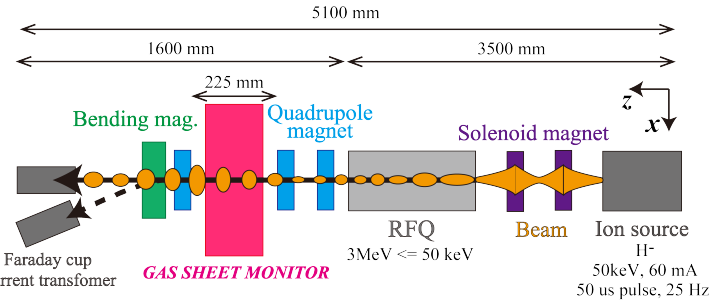
➔ **Issue: feedforward system is not optimized in terms of beam profile**

➔ **Time evolution of beam profile was measured with GSM to investigate stability of beam profile against feed-forward system**



J-PARC 3 MeV-Beam-Line Test Stand

Negative Hydrogen Ion Beam: 3 MeV, 60 mA, 50 us pulsed, 25 Hz



Gas Sheet Monitor

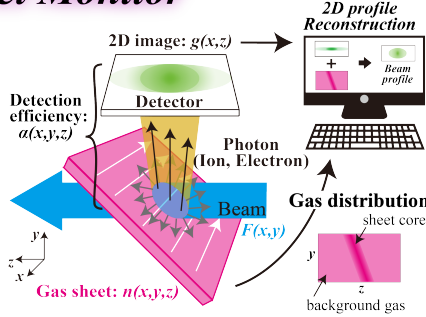
Principle of Gas Sheet Monitor

- Injecting a sheet-shaped gas
- Producing photons
- Detecting photon spatial distribution as a 2D image

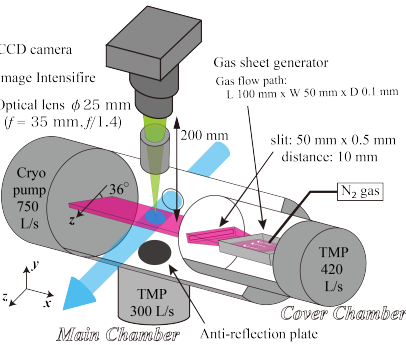
For ideal gas sheet
Photon distribution = beam profile

For realistic gas sheet
Profile reconstruction is necessary

Photons produced where beam exists is integrated on detector

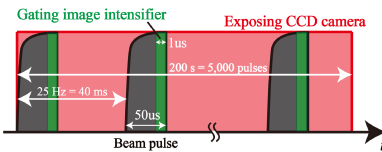


$$g(x, z) = \int_D \alpha(x, y, z) n(x, y, z) F(x, y) dy = \int_D k(x, y, z) F(x, y) dy$$



Developed GSM System

- Forming N2 gas sheet
- Cutting sheet tail w cover chamber
- Detecting photons w CCD camera: 16 bit, 1920 x 1080
- Image intensifier: gain 10⁴ times



Profile Measurement

Gas pressure

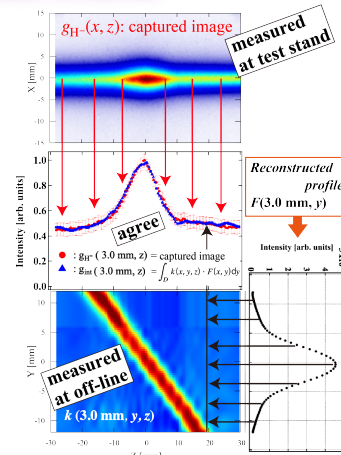
Sheet generator inlet: 100 Pa
Main chamber of GSM : 5.6 x 10⁻⁵ Pa
(=Background, Base: 4 x 10⁻⁷ Pa)

Averaging

Image intensifier gate : 1 us
CCD camera exposure: 200 s
=> 1 us x 25 Hz x 200 s x 15 frames
(3,000 s, 1.5 uA DC beam equivalent)

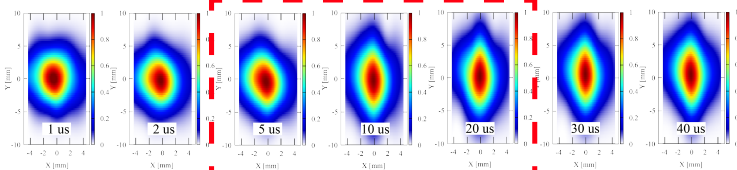
Reconstruction

Spatial resolution : 1 mm
Analysis error + Standard deviation : 8.4-12%

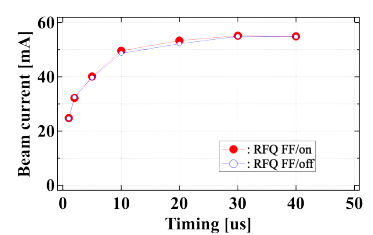
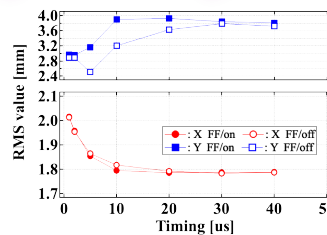
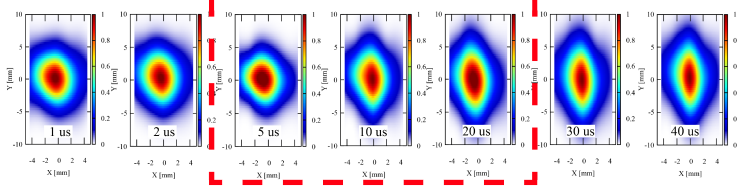


Time Evolution of Beam Profile

w/ feedforward control



w/o feedforward control



After 10 us: Feedforward control makes beam profile stable
First 10 us: Feedforward control may not be optimized or beam profile depends on space-charge force because beam current doubles in first 10 us

➔ **GSM can measure time evolution of beam profile and provide a new perspective for beam operation and study**