GAS JET BASED ONLINE BEAM MONITORING FOR ADVANCED PROTON THERAPY FACILITIES

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Abstract

Proton therapy offers precise dose conformity with minimal impact on organs at risk, but quality assurance is challenging, particularly with emerging facilities like LhARA for FLASH therapy. Existing techniques like SEM Grid and Ionization chambers struggle in the FLASH regime due to the ion recombination effect and lack of real-time feedback. This study introduces the gas jet monitor as a non-invasive solution leveraging ionization of the gas due to the gas curtain-beam interaction to measure beam profile without perturbing the beam. Equipped with fast-response detection, it enables online monitoring, reducing calibration time and enhancing treatment efficacy. Optimization of parameters such as sensitivity and jet density, along with experimental validation, is crucial for proton beam dosimetry. The gas jet monitor shows promise in overcoming limitations of conventional techniques, facilitating advancements in FLASH therapy.

Introduction

Proton therapy is adapting novel treatment techniques using instantaneous high dose rate for the better treatment efficacy. The facilities like LhARA(Laser-hybrid Accelerator for Radiobiological Application) enables the advanced treatment modalities like FLASH. The high dose rate and requirement of real time monitoring limits dosimetry of Proton beam therapy using conventional diagnostic techniques, which also requires periodic calibration tests.

Conventional Dosimeters

Ionization Chambers

Ionization chamber, given in Fig. 1 is considered as the gold standard of dosimetry in radiotherapy.

In high dose rate scenarios, the ion recombination effect is present which, in effect, will return inaccurate measurements. Lack of real-time feedback is another limitation

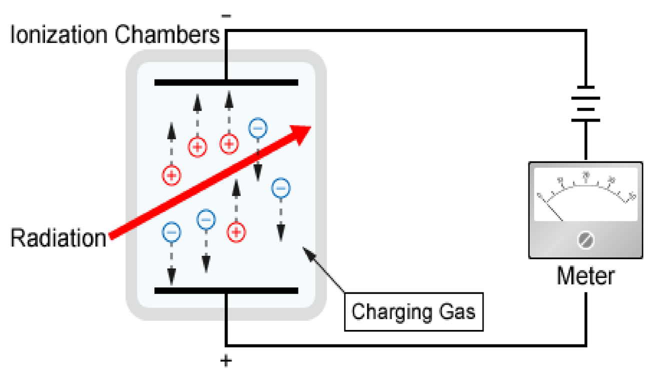

Fig.1. Ionization chamber

SEM Grid

Secondary Electron Emission grids, presented in Fig.2 are based on the secondary electrons released from the grid wires up on ion beam impact. SEM is expensive and it perturbs the beam.

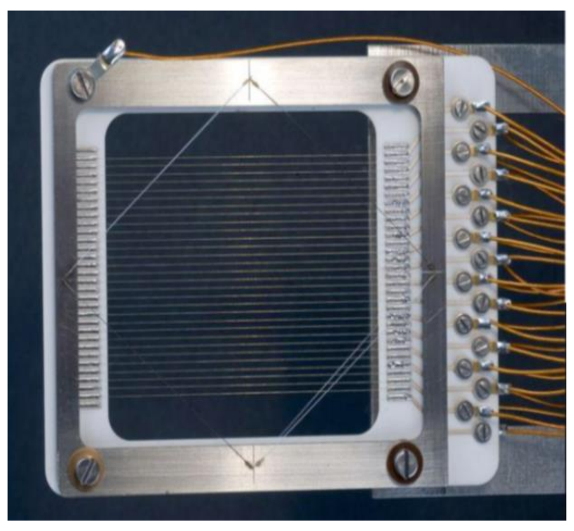

Fig.2. SEM Grid

There are other conventional diagnostic techniques like scintillating screen, Faraday cup, etc. The main limitations associated with these are the calibration requirements, invasiveness and limited live feedback.

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Gas jet-based monitor

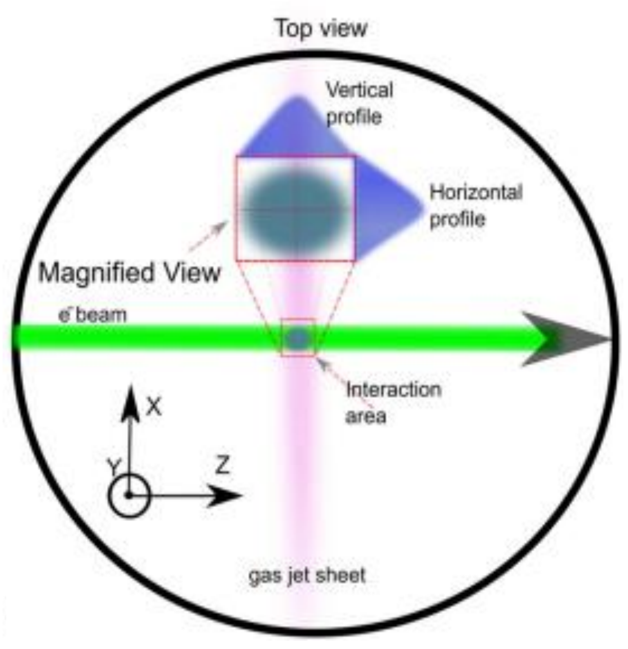

Fig.3. Schematic of the particle beam-gas jet interaction

- Gas-jet system measures the beam profile, by detecting the ions produced by the interaction of ion beam with gas curtain, as depicted in Fig.3.
- The curtain formation begin by generating a supersonic gas jet through the adiabatic expansion of high-pressure gas in a vacuum.
- Extract the supersonic core using skimmers.
- Reshape the core into the desired gas curtain configuration.
- Inject the gas curtain perpendicular to the beam, with a 45-degree inclination

The ions produced by the interaction of ion beam with gas curtain are drifted towards the detector system (MCP+ phosphor screen+ Camera) with the help of extraction system given in Fig.4, in which electrodes are biased with certain potentials.

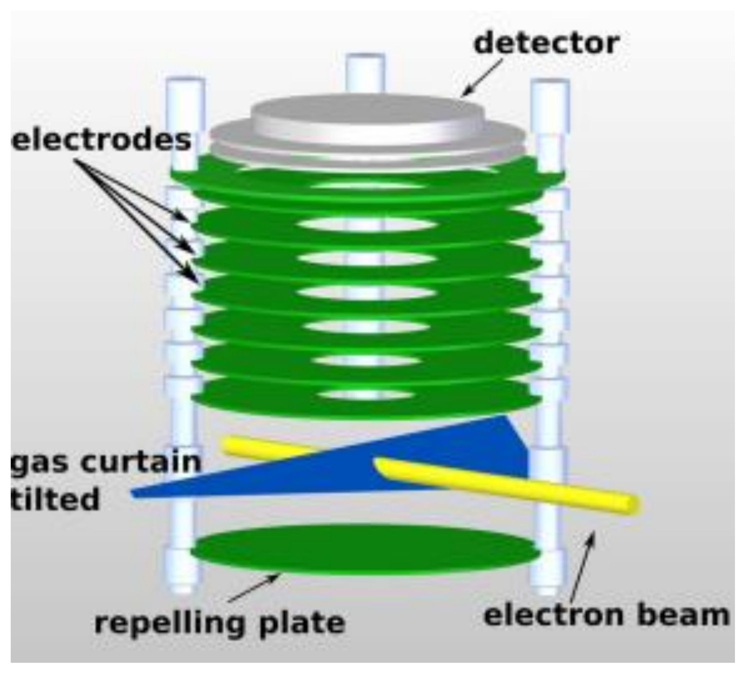

Fig.4. Schematic diagram of extraction system

Gas-jet system as a Dosimeter

For the diagnosis of therapeutic proton and light-ion beams, need to explore the below in detail:

- Advanced detection systems.
- Optimized jet profile.
- Selecting the gases according to the beam to get higher ionization cross section.
- Improvement in reconstruction of data (Machine Learning).

Conclusion

After upgrading the existing gas-jet system as mentioned above, a novel non-invasive diagnostic technology can be developed and integrated into the advanced proton and light ion beam therapy facilities.

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