Gas Mixing: a tool for Improving Resolution of Non-Invasive Gas-Jet Based Ionization Profile Monitor for Low Energy Beams

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Abstract

Ionization profile monitors (IPM) using a supersonic gas jet as target are an attractive tool for the characterization of low energy beams. In this scheme, a primary beam crosses a 45-degree tilted thin gas curtain and this interaction causes ionization of gas molecules in the jet. An electrostatic extraction system is used to collect the generated ions in order to determine the 2D transverse profile of the primary beam. The most commonly used gases for the jet are Helium and Nitrogen. The signal from the gas jet is always super-imposed with the signal resulting from residual gases in the interaction chamber. CST simulations indicate that the gas jet velocity is a key factor for the separation of the jet and residual gas signals. To obtain a good signal separation, one can increase the velocity of the gas jet. This can be accomplished by generating a gas jet after mixing heavier gases into lighter gases. This contribution gives a general overview of the monitor design, discusses jet formation and results from simulations. It also presents experimental results obtained with Helium, Nitrogen, as well as a mixture of them using different percentages and the impact on measurement resolution..

System Outline

1. Gas-jet formation

- A supersonic gas jet is generated as a high pressure gas flows through a 30 μm nozzle.
- 2 stage of skimming with conical skimmers 180 μm and 400 μm and a third curtain shaping 4*0.4 mm^2 pyramid skimmer.
- The ionization induced by the excitation of the gas molecules by the electron beam is detected to produce a 2D transverse profile of the beam .

2. Prototype Schematics

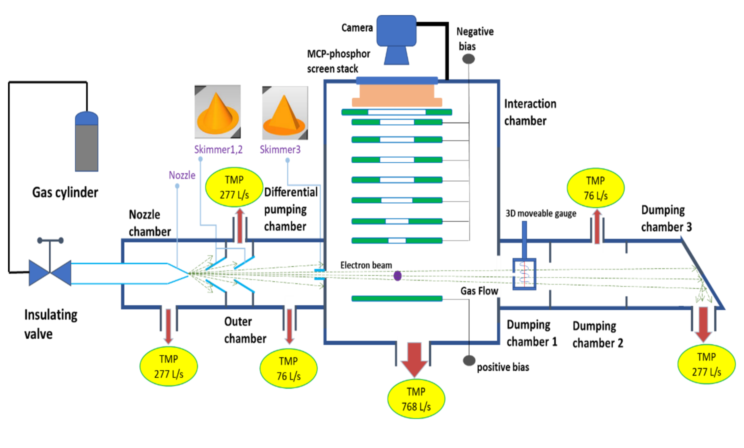

Figure 1. Schematic of a prototype gas curtain based beam profile monitor using beam induced ionization. The turbo-pumps are connected to three nXDS15i scroll pumps.

- Differential pumping technique is used with the operating pressure of each chamber.
- A gas separator is placed in the skimmer chamber, dividing the volume between the skimmers.
- The extraction system consists of repeller plate, concentric rings with increasing potentials known as MCP and Phosphor screen.

Profile Measurements

- The gas species taken under consideration were nitrogen and helium and mixture of nitrogen and helium having ratio of 5:1 respectively.
- For the aligned system under optimum conditions, using nitrogen (at various pressures), to measure the 1D profile of a 5 keV electron beam carrying with a filament current of 2.60 A.

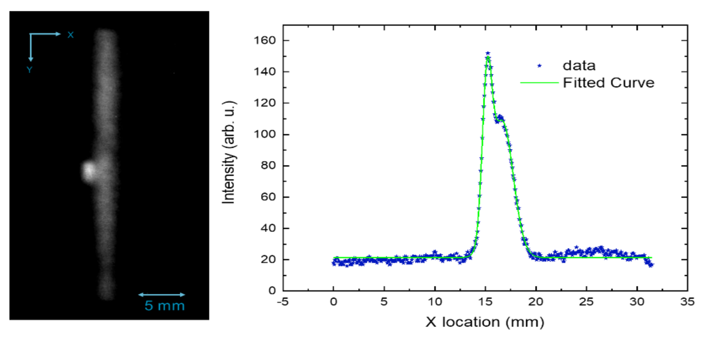

Figure 2. Transverse profile of an electron beam measured from the ionization of a helium gas curtain.

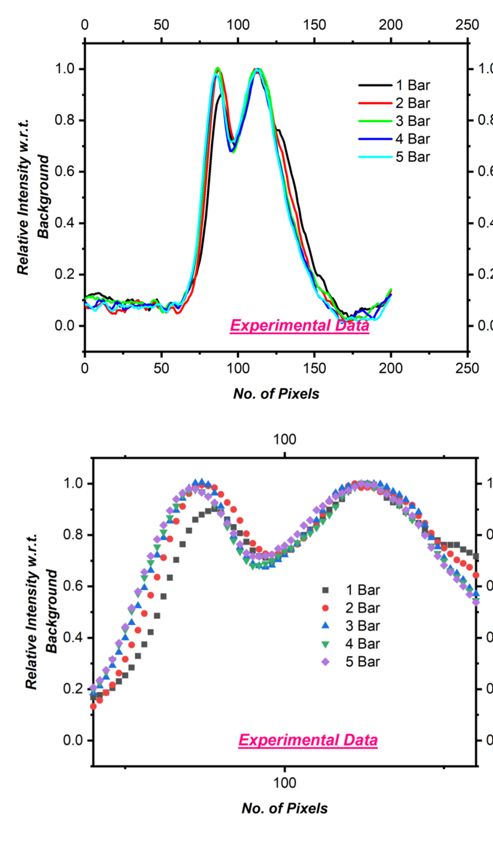

Figure 3. Transverse profile of an electron beam measured from the ionization of a nitrogen gas curtain. (Upper image) Whole profile and (lower image) zoomed version of same profile indicating almost similar profile for 2 bar and higher injection pressures.

•Mixed gas was injected at 2 bar pressure and 1D profile measurement has been carried out for 4500 seconds.

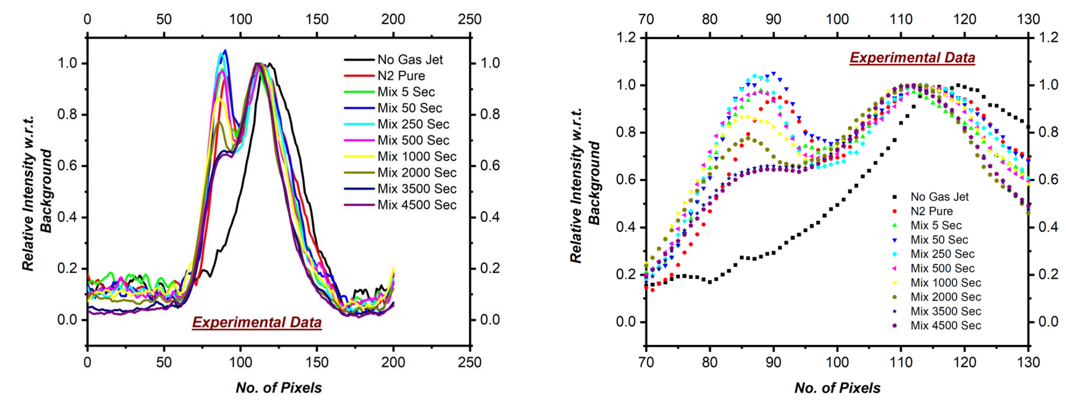

Figure 4. Transverse profile of an electron beam measured from the ionization of a mixture gas curtain of nitrogen and helium (5:1) gases. (Left image) Whole profile and (Right image) zoomed version of same profile indicating change in profile over time for 2 bar injection pressure.

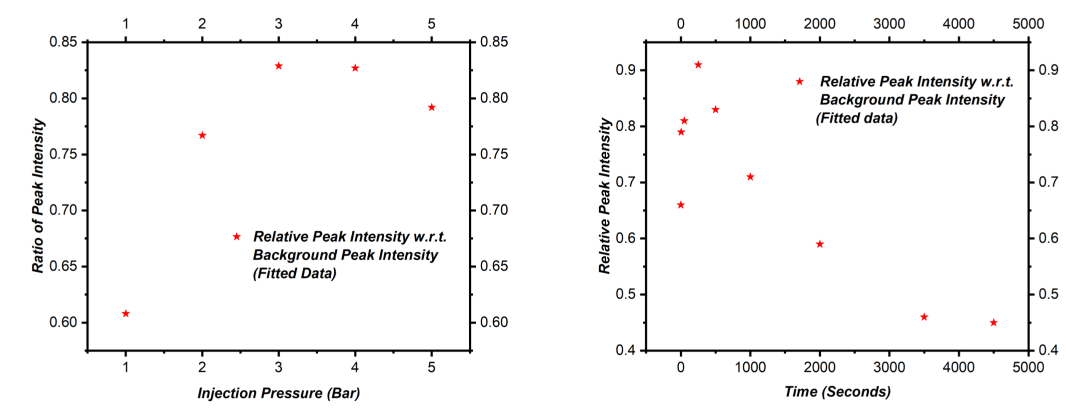

Figure 5. Relative peak intensity w.r.t background peak intensity obtained from the Gaussian fitted data. (Left image) for nitrogen gas curtain at different injection pressures and (Right Image) for 2 bar injection pressure of mixed gas.

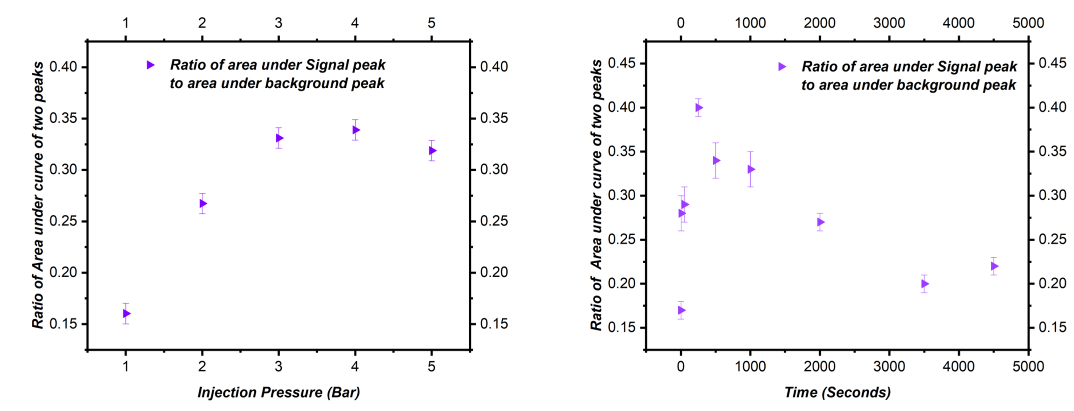

Figure 6. Ratio of area under signal peak to background peak obtained from the Gaussian fitted data. (Left image) for nitrogen gas curtain at different injection pressures and (Right Image) for 2 bar injection pressure of mixed gas.

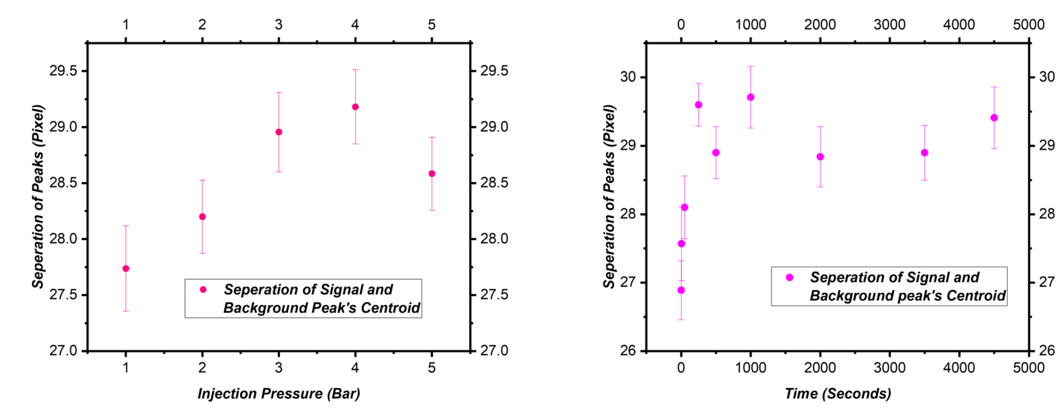

Figure 7. Separation of signal and background peak's Centroid obtained from the Gaussian fitted data. (Left image) for nitrogen gas curtain at different injection pressures and (Right Image) for 2 bar injection pressure of mixed gas.

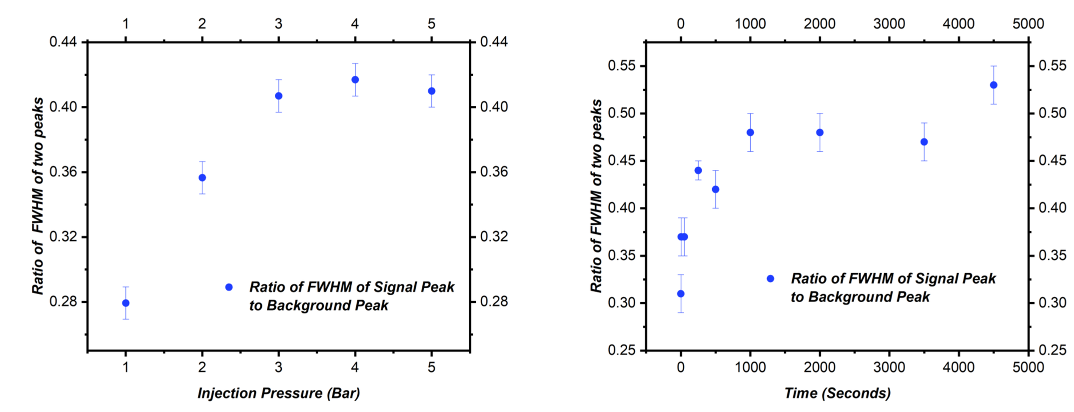

Figure 8. Relative FWHM of signal w.r.t background FWHM obtained from the Gaussian fitted data. (Left image) for nitrogen gas curtain at different injection pressures and (Right Image) for 2 bar injection pressure of mixed gas.

CST Simulations

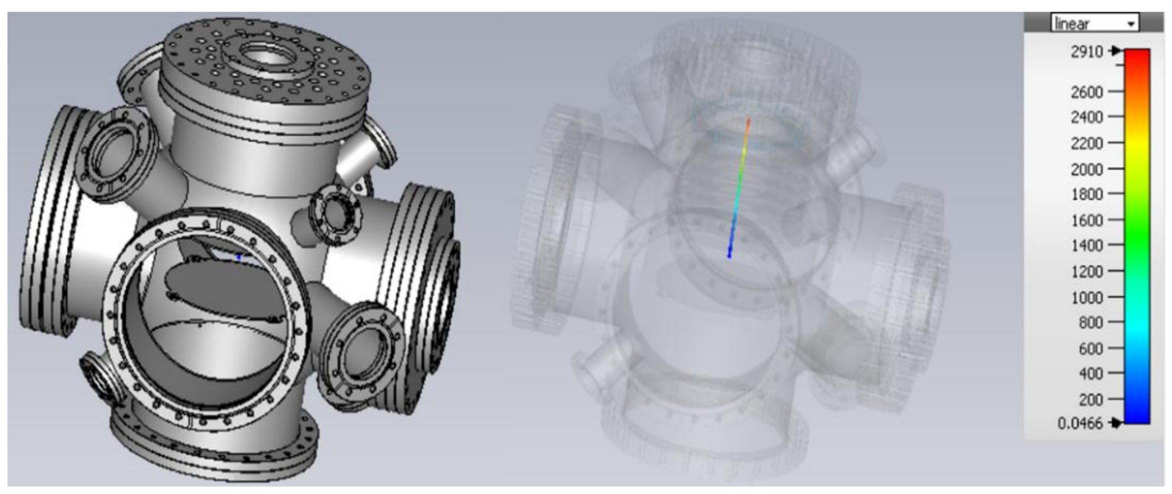

Figure 9. CST PIC solver simulations of supersonic He+ jet trajectory under the influence of electrostatic field.

- CST PIC solver simulations were performed for the similar voltages applied on extraction system as were applied for experimental measurements.
- For same velocity, the higher mass's gas species used for gas curtain will have more separation as compared to lighter mass and for same gas species, higher the velocity of jet: more will be signal separation.

Conclusion

In this contribution, the progress on the development of a supersonic gas-curtain based profile monitor has been presented. It has been demonstrated that this device can be used as a viable profile monitor that utilises the beam induced ionization in the gas curtain. The use of nitrogen, helium and their mixture as working gases was demonstrated and it was observed that mixture may offer a better signal to noise ratio for similar injection pressure. For a given injection system, the resolution obtained for 2 bar of injection pressure of mixed gas is similar to resolution obtained for 4 bar of injection pressure of nitrogen gas. The time variation of signal for mixed gas curtain is because of changing composition of mixture. This device would be highly desirable for non invasive beam profiling for low energetic beams.

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