DEVELOPMENT OF QUANTUM GAS JET BEAM PROFILE MONITOR FOR SUB-MM BEAMS

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Abstract

The development work of a high-resolution quantum gas jet beam profile monitor for highly energetic sub-mm particle beams is in progress at the Cockcroft Institute (CI), UK. This device is designed on the principle of detecting the secondary ions from the ionisation induced in the interaction between the quantum gas jet and charged particle beams. This monitor aims to generate an intense gas jet with a diameter of less than 100 μm, which can ultimately lead to superior position resolution and high signal intensity resulting from a strongly focused quantum gas jet. This is done by exploiting the quantum wave feature of the neutral gas atoms to generate an interference pattern with a single maximum acting as an ultra-thin gas jet using an 'atom sieve' which is similar to the light focusing with a Fresnel zone plate. This device will be minimally interceptive and will work analogously to a mechanical wire scanner. This contribution gives a general overview of the design, working principle of the monitor and experimental results obtained from the electron beam profile measurements carried out at CI.

System Outline

1. Gas-jet formation

- A supersonic gas jet is generated as a high pressure gas flowing through a 30 μm nozzle.
- 3 stage of skimming with skimmers 400 μm, 2 mm and pinholes of varying sizes and a 3rd skimmer of 3.5mm for vacuum isolation.
- 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 .

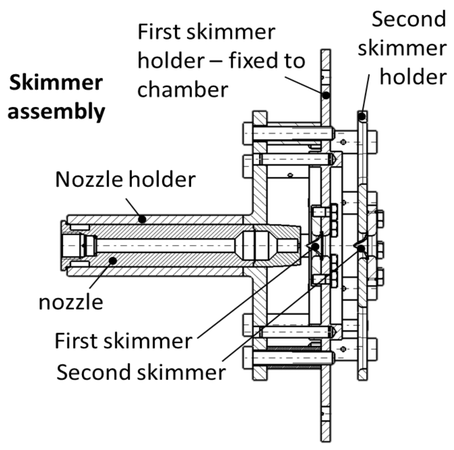
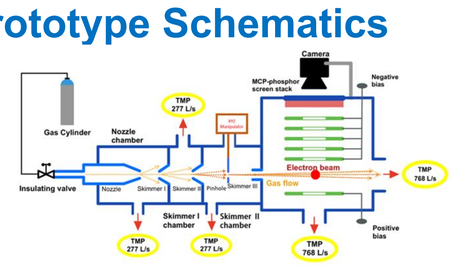


Figure 1. Detailed schematic of the nozzle-skimmer assembly. Alignment of the nozzle and the skimmers is possible off-line only.

2. Prototype Schematics



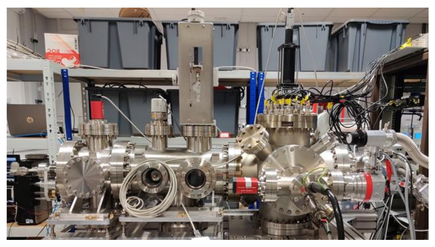


Figure 2. Schematic of a prototype gas curtain based beam profile monitor using beam induced ionization. The turbo-pumps are connected to three nXDS15i scroll pumps.

- Differential pumping technique is used with the operating pressure of each chamber displayed in Table 1.
- A gas separator is placed in the skimmer chamber, dividing the volume between the skimmers.
- The imaging system contains an electrostatic extraction system, a MCP, a phosphor screen and a camera.

Chamber	Pressure
Nozzle Chamber	2.90E-3 mbar
Skimmer Chamber 1	5.90E-6 mbar
Skimmer Chamber 2	6.10E-7 mbar
Interaction Chamber	1.38E-8 mbar

Table 1 Background gas pressure in each chamber with the electron gun on and the inlet pressure for the jet set to 5 bar.

Profile Measurements

- The gas species taken under consideration were nitrogen and helium.
- The experimental work was initiated with installing pinholes of various sizes ranging from 1mm to 50μm. Pinhole acted as an additional aperture and provided the circular supersonic gas jet to interact with electron beam having energy of 3.7keV and filament current of 2.6A.
- The x-profile's sigma is dependent on the size and part of the beam interacting with the gas jet so the σ is different for each measurement.
- The y-profile's sigma is dependent on the size of gas jet originated from different pinholes, hence the σ decreases till 100μm and for 50μm, σ is higher than for 100μm pinhole.

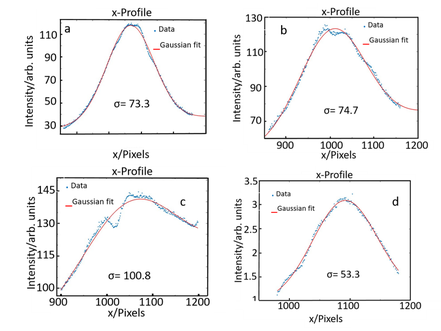


Figure 5. X beam profile obtained for various pinholes diameters: (a) 500μm, (b) 200μm, (c) 100μm and (d) 50μm.

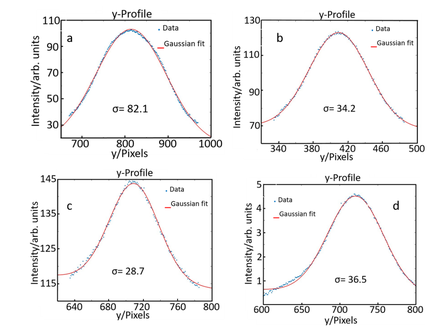


Figure 6. Y beam profile obtained for various pinholes diameters: (a) 500μm, (b) 200μm, (c) 100μm and (d) 50μm.

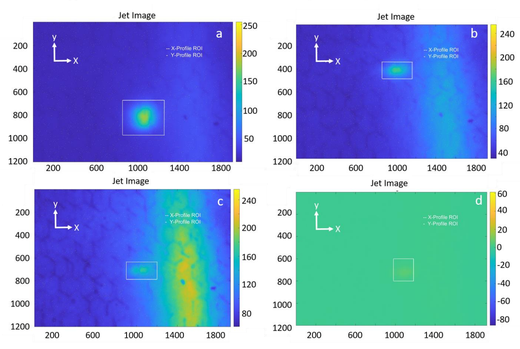


Figure 4. Beam profile images obtained for various pinholes diameters: (a) 500μm, (b) 200μm, (c) 100μm and (d) 50μm. The integration time for each image is 6, 9, 30 and 300 seconds respectively.

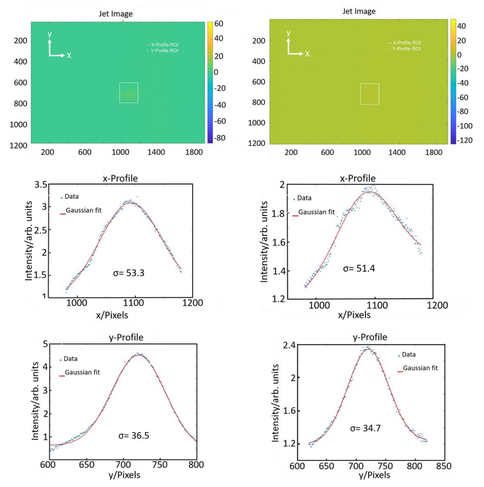


Figure 7. Beam profile image obtained for 50μm pinhole along with X and Y profiles for the same electron beam at two different location for gas jet separated by a distance of 200μm.

Atom sieve design

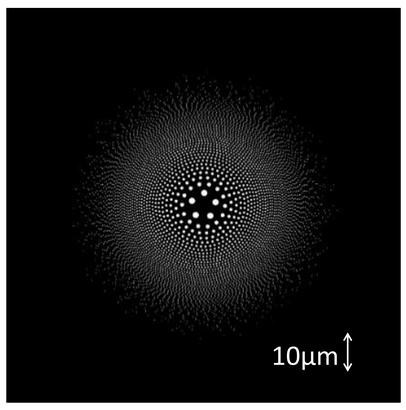


Figure 3. Design of the atom sieve on Si wafer (dia. 150 mm)

- FZP for x-rays is made up of concentric metallic rings embedded in an x-ray transparent substrate. However for an atom sieve, holes are required to provide the passage for the gas molecules.
- The atom sieve is fabricated on a 2μm thick silicon nitride membrane grown on a silicon wafer of diameter 150mm. The circular holes in the pattern are within 60μm diameter.
- The pinhole/atom sieve is mounted on a vacuum compatible xyz manipulator which provides the flexibility in the movement in x and y directions and helps in scanning the primary beam. The movement in z direction will assist in focusing the quantum gas jet at desired location with respect to the nozzle and interaction point for imaging.

Conclusion

- ❑ The progress on the ongoing development of a quantum gas jet based profile monitor has been presented.
- ❑ This device can be used as a viable profile monitor that utilises the beam induced ionization in the gas jet for high power accelerators.
- ❑ The work on improving the gas jet density using atom sieve and optimizing of the design of the monitor in order to ease the integration into the complex accelerator structure is currently in progress.
- ❑ This new design of the monitor will make it useful for an even wider range of accelerators and in other relevant research areas i.e. microscopy, plasma physics, etc.

Acknowledgement

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