Mass spectrometer interface visualisation techniques in atmospheric pressure and vacuum sections

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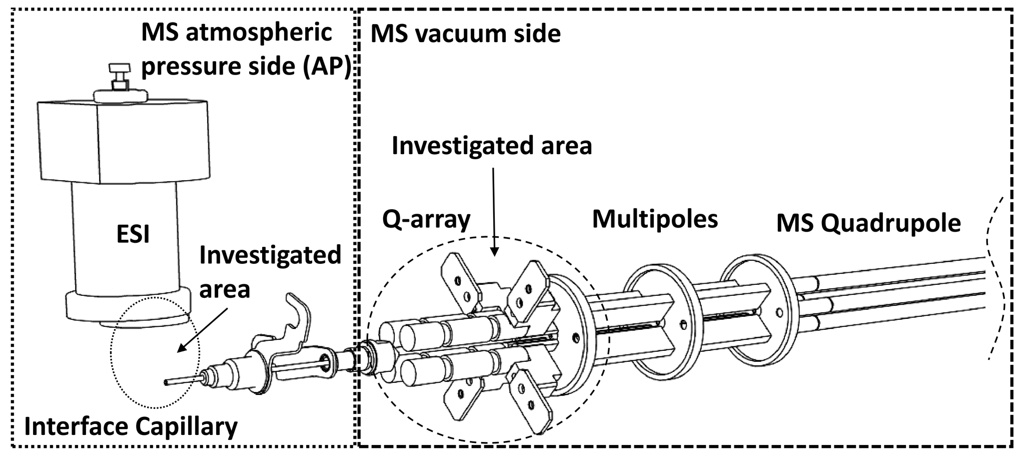
1: Introduction

- A mass spectrometer's sensitivity is directly connected with the gas intake from the ESI chamber into the vacuum side of the MS. To see, helps to understand; understand, helps to improve. We are presenting two novel techniques, one for visualisation of ESI droplets in atmospheric pressure and one for visualisation of the supersonic gas jet entering the first low pressure mass spectrometer region.

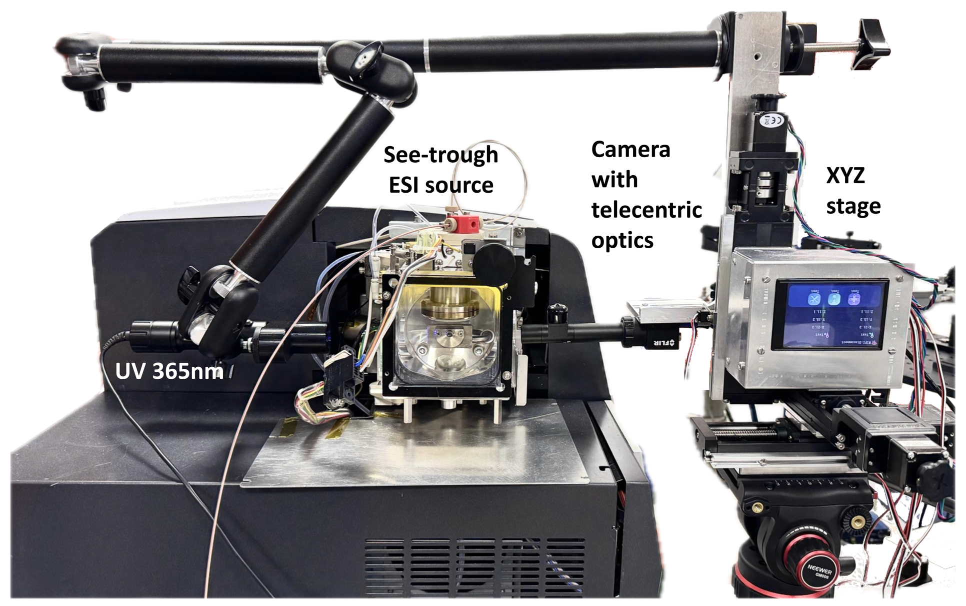


AP side performance depends on how ions/droplets are generated towards the Interface Capillary. The capillary desolvates remaining droplets and delivers ions into the MS vacuum inside a supersonic gas jet. The shape and how well this gas jet fits between electrodes is responsible for effective ion capture.

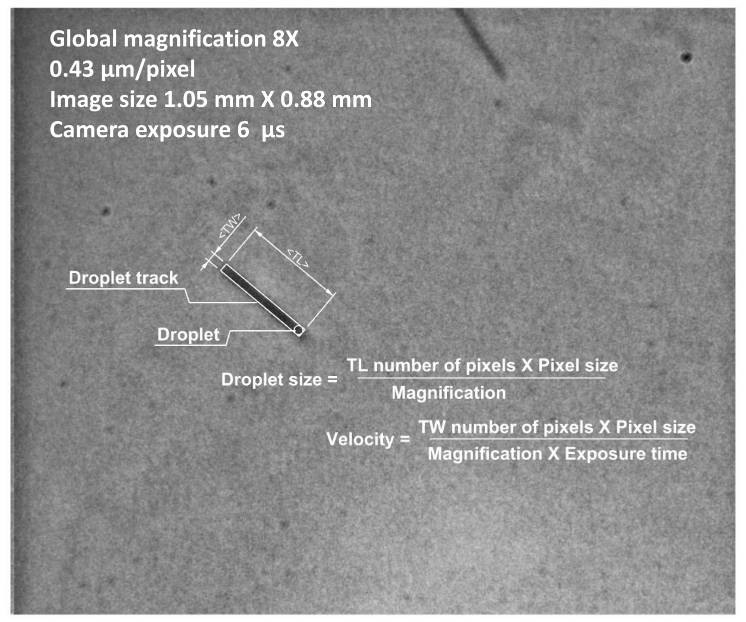
2: High Speed Microscope Photography

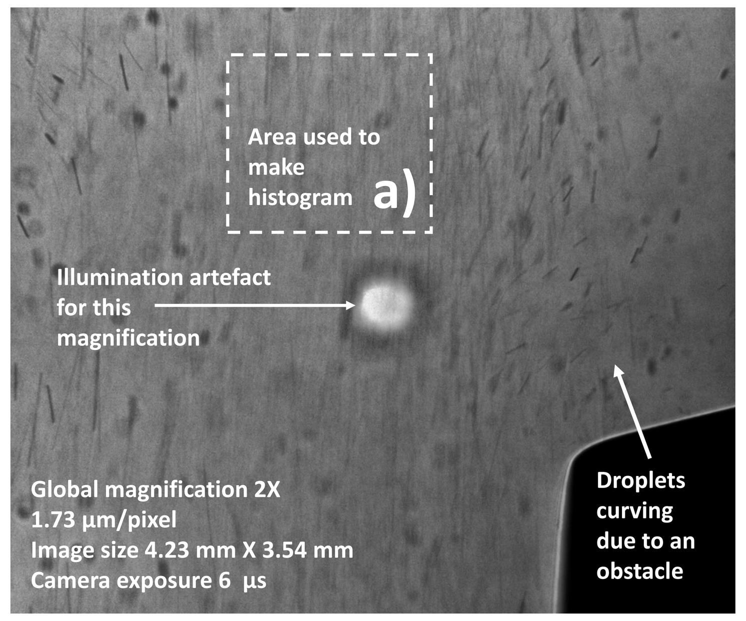
We developed a 3D ESI droplet scanner, composed of:

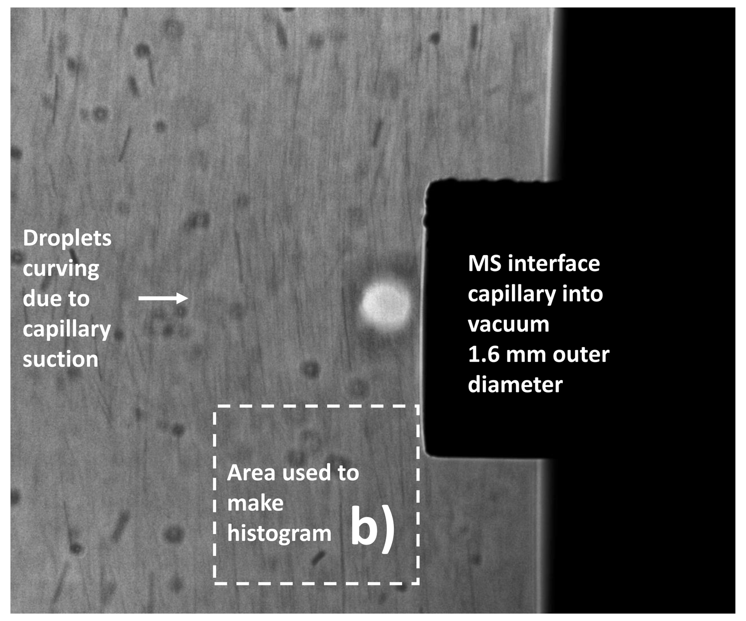
I. Fast photographic camera with telecentric optics
II. High power UV light source for the bright field mode
III. Robotized XYZ stage moving the camera together with the light source
IV. Image recognition software



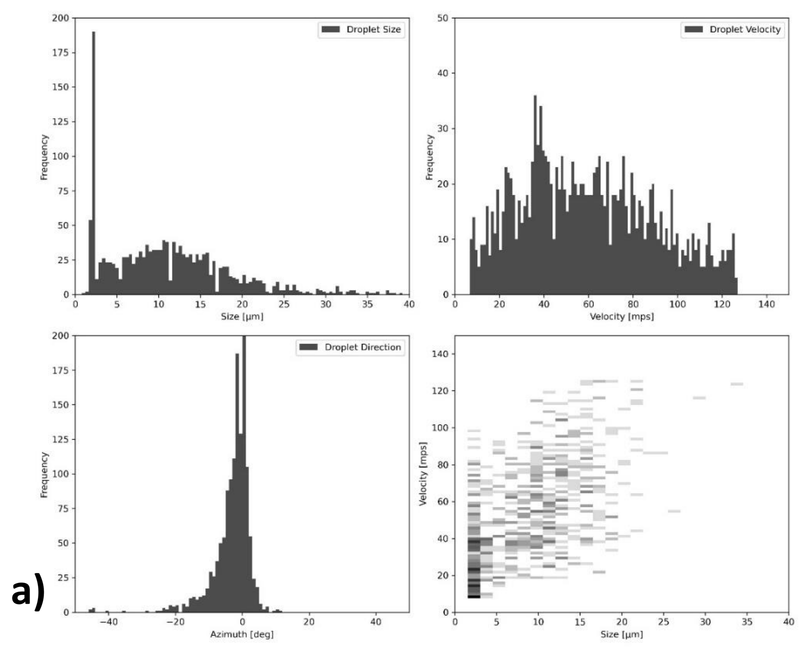
The ESI conditions were set to obtain lower droplets velocities for better visualisation: LC sample buffer flow 0.3 mL/min, nebulising gas 0.5 L/min and Heating Gas 5 L/min and 160 C°, Interface Voltage 4 kV

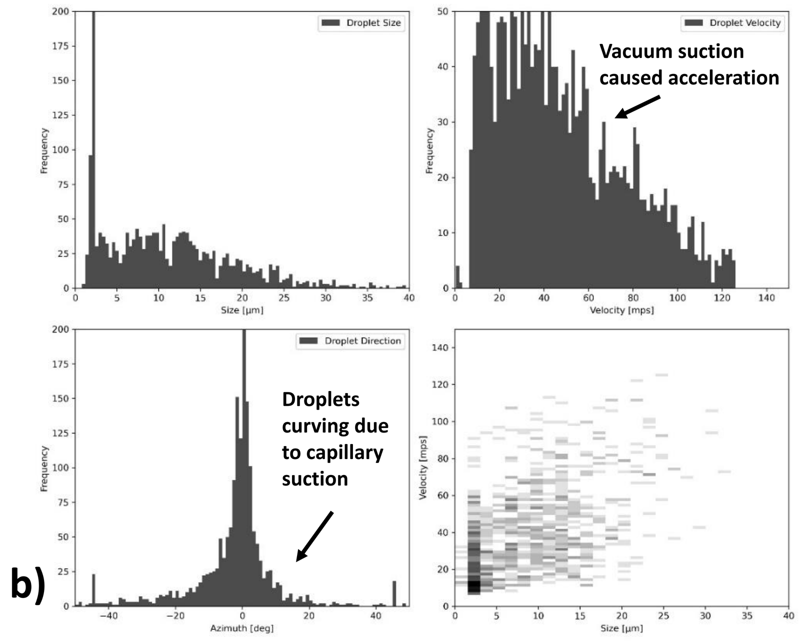






Droplets histograms (1 mm X 0.9 mm), size, velocity and direction



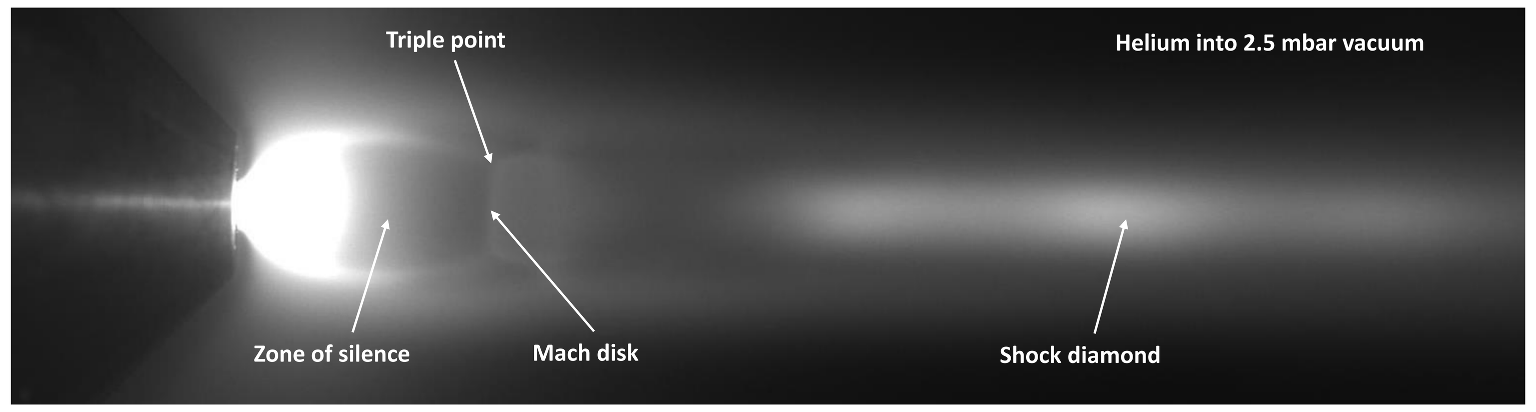


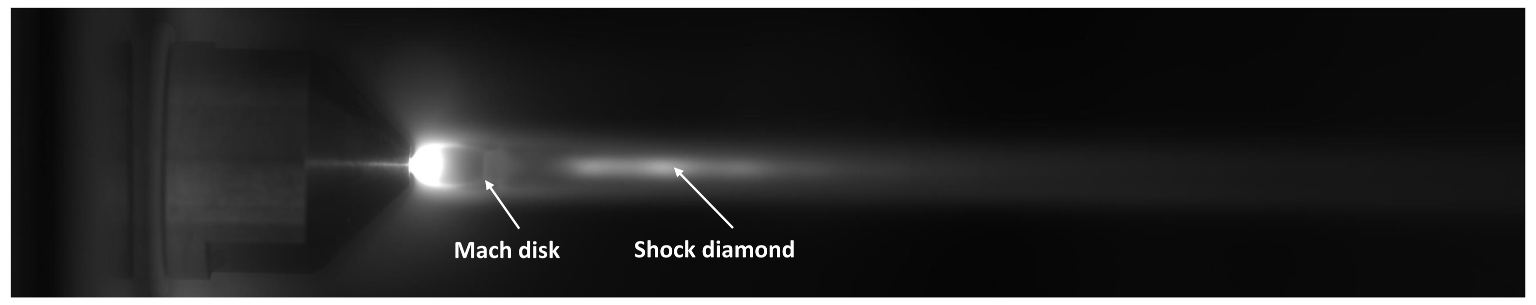
Droplet detection/extraction:

1. Increasing contrast using Contrast-Limited Adaptive Histogram Equalization (CLAHE)[1]
2. Cropping to remove any artifacts at the edges of the image that could generate false positives
3. Non-Local Means (NLM)[1] filtering to de-noise/smooth the image
4. Increasing brightness to better define the droplet
5. Sharpening using a sharpening kernel to better define the droplet
6. Edge Detection using Canny algorithm[1]
7. Line detection of the edges using Hough algorithm[1]
8. The lines are isolated on a black background
9. Contouring algorithm to bound the lines into a single shape

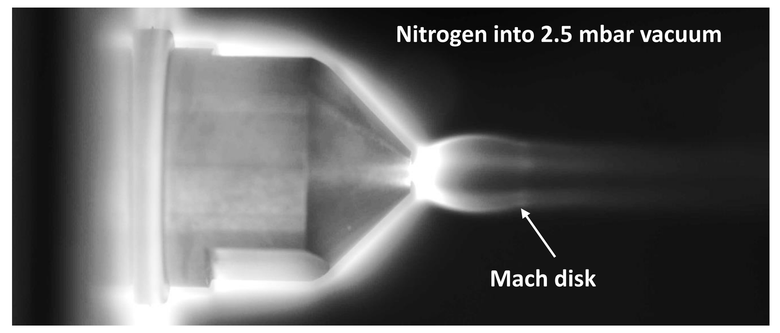
3: AC Electric Discharge type visualisation

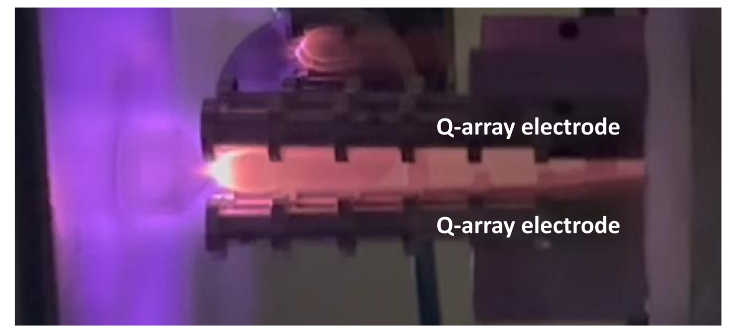
- To visualize the supersonic gas jet plume on the MS vacuum side we used a novel high voltage AC electric discharge method, similar to electric glow discharge[2]. A transparent vacuum chamber was made to conduct these experiments. The plasma discharge was only present around the exit of the Interface Capillary, yet the whole supersonic gas jet was visible.

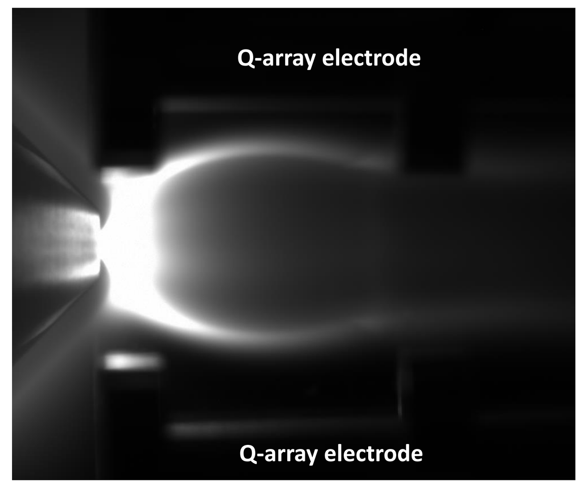


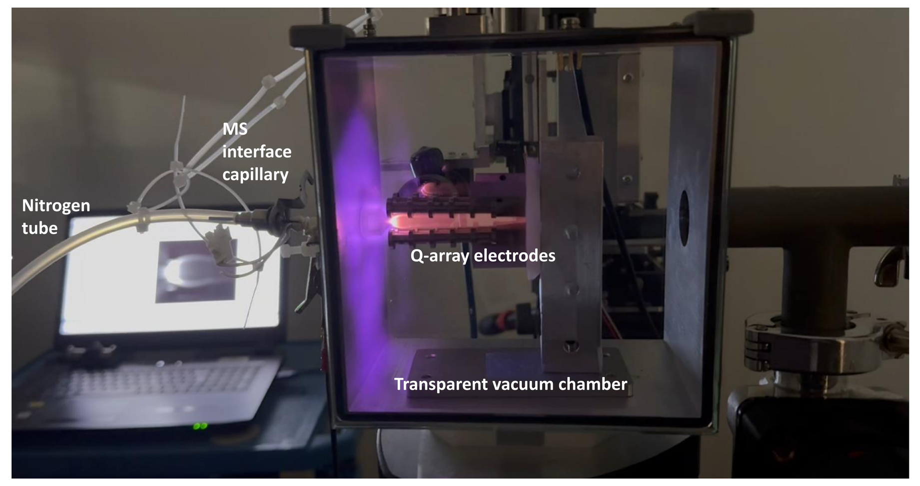


- To visibility of the supersonic gas jet reached far beyond the plasma region. It was possible to install Q-array electrodes in the chamber without reducing gas jet brightness. Interaction of the gas jet with inserted objects could be investigated.

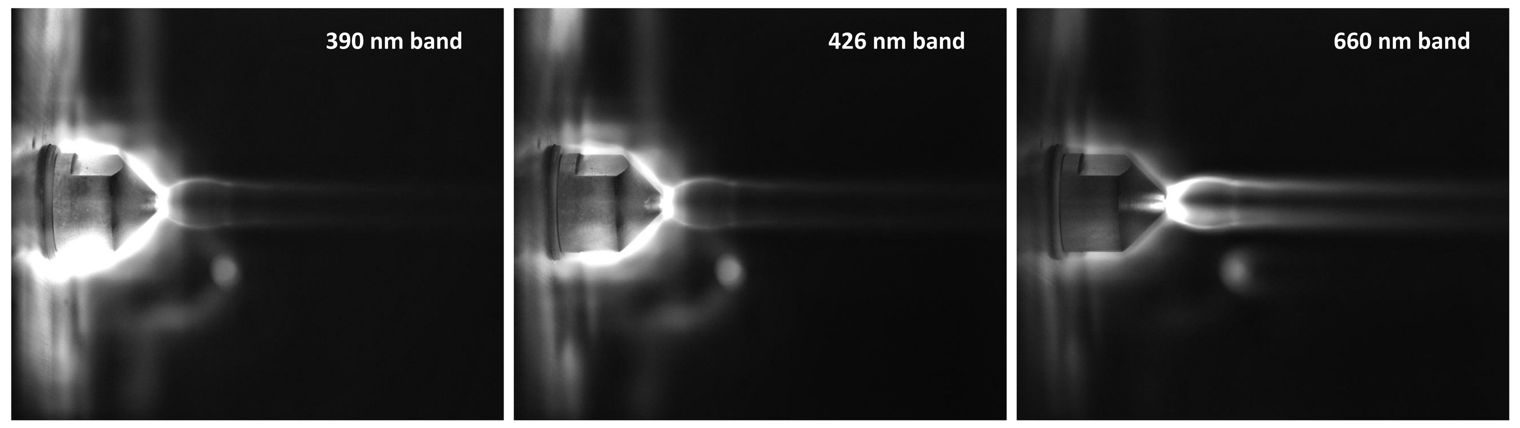




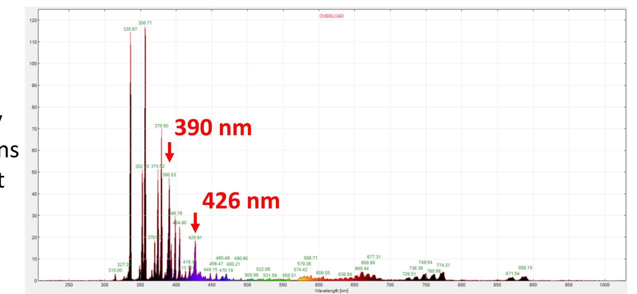




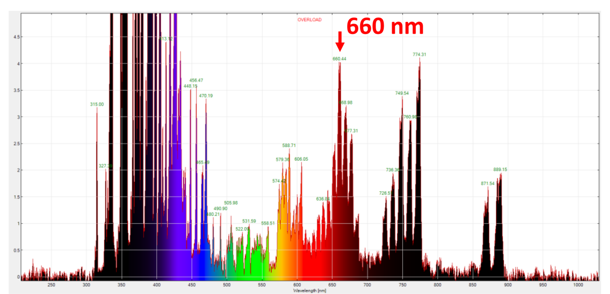
- Bandpass (10 nm) dichroic filters were used, adjusted to selected nitrogen spectrum peaks, to perform spectral photography.
- The plasma region is limited to the Orifice (MS interface capillary exit holder). What can be observed when making images is photons originating from the transition between different electronic energy level in nitrogen atoms[3].
- The supersonic gas jet is visualised mainly due to photons originating from transitions between different vibrational energy levels of nitrogen molecules[3]. This is independent of the electric field.



- 390 nm and 426 nm photos are similar
- They are made by electron transitions between different energy levels in N atoms



- 660 nm image is part of N_2 molecule transition between different vibrational energy levels



4: Conclusions

- These two visualisation methods were developed as tools for MS sensitivity improvement R&D.
- ESI droplet mapping provides detailed maps for each setup conditions.
- Visualisation of the supersonic gas jet allows shape optimisation as well study of interaction with of the gas jet with objects. It is a fast and easy method providing understanding of a region of the MS which previously was only accessible through complex CFD simulations.

References

1. https://opencv.org/
2. "High frequency AC electric glow discharge visualization technology and application in big diameter hypersonic low-density wind tunnel", Wanqiu Jiang et al., *Advances in Aerodynamics volume 3, Article number: 14 (**2021**).*
3. "Study of positive column of glow discharge in nitrogen by optical emission spectroscopy and numerical simulation", G. Cicala, et al., *Plasma Sources Sci. Technol. 18 (**2009**) 025032.*