The design and construction of a near-ambient pressure velocity map imaging apparatus

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Introduction

- Velocity map imaging[1] techniques have widely used in molecular dynamics studies or experiments, but due to the working pressure of MCP detectors, the reaction can only occur under high vacuum condition. In this study, we present a new velocity-map imaging system that can be used to study processes occurring at near-ambient pressure.
- The required differential pumping between ionization and detector regions is achieved by the addition of a small aperture. Ions are guided to a hard focus at the aperture by the extraction optics before being velocity mapped by a second set of electrodes.

Methods

- VMI optics are designed to be compact, due to the mean free path decreases with elevating pressure.
- COMSOL multiphysics simulation is performed for VMI configuration and ion trajectory.
- This equipment consists of Laser source, reaction chamber and MCP chamber.
- VMI and DC slicing[2,3] are demonstrated for photodissociation of leaked N_2O at ~203 nm, the mean speed and anisotropy parameter are in agreement with the literature data[4].

Next Steps

- This system is being developed as part of a molecular beam surface scattering instrument.
- The technique may be applied in a range of other areas where higher pressures are either interesting or unavoidable, e.g. with liquid jets and surfaces.

Acknowledgments

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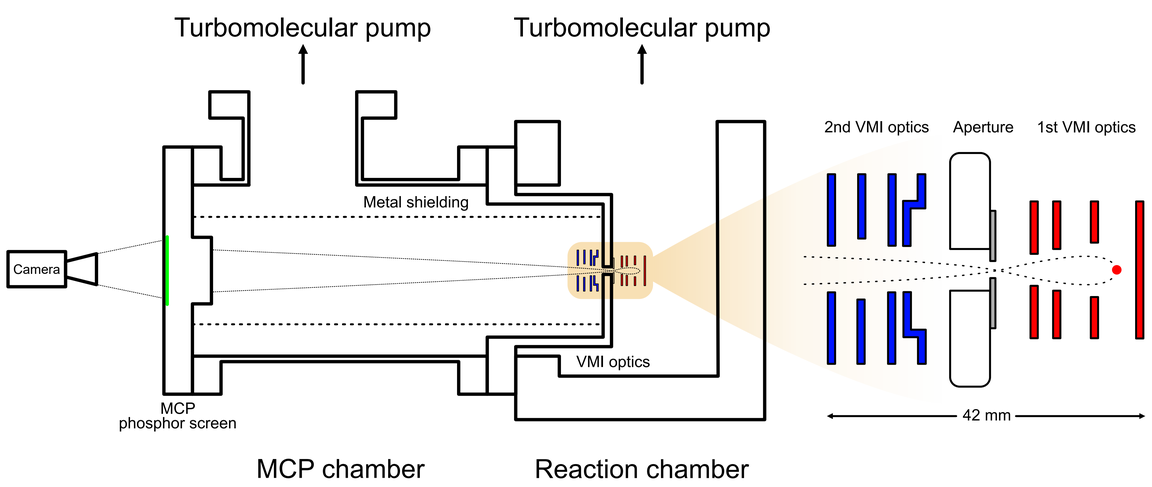
References

[1] Review of Scientific Instruments **68**, 3477 (1997)
[2] Review of Scientific Instruments **74**,2530 (2003)
[3] Review of Scientific Instruments **74**, 2495 (2003)
[4] The Journal of Chemical Physics **110**, 3411 (1999)
[5] The Journal of Physical Chemistry A **119**, 12255 (2015)

Near-Ambient Pressure Velocity Map Imaging achieves with differential pumping and extra electrodes

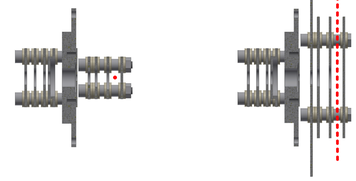


Scan QR code with your camera to access the video on Youtube

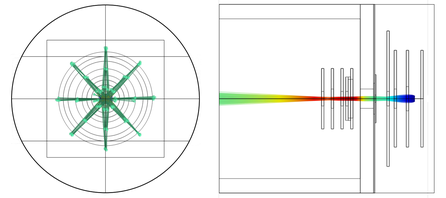
Lens Design

The cross section of VMI optics in side view and top view, red line indicates the laser propagation.

Side view Top view

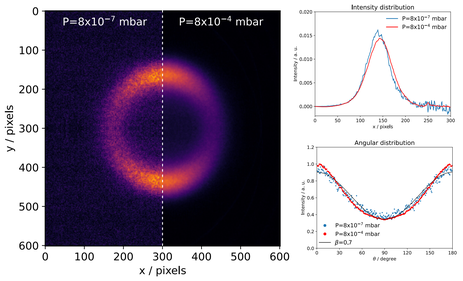


Simulation

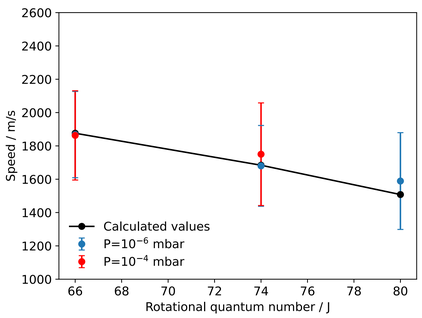


- Simulation of N_2^+ trajectory with 0.03, 0.27 and 0.75 eV of kinetic energy in 8 directions.
- The initial positions are center, 0.5 and 1 mm apart along the laser propagation.

NAP-VMI



- DC sliced images for photodissociation of leaked N_2O under pressure (a) $8x10^{-7}$ and (b) $8x10^{-4}$ mbar.
- Intensity distribution and angular distribution from the DC sliced images.



- Plot of mean speed for individual J state of N_2.
- The experimental speed distribution can be fit with a flowing Maxwell–Boltzmann distribution[5]:

$$f(x) \propto v^3 exp^{-\frac{(v-v_0)^2}{\alpha^2}}, \ \alpha^2 = 2k_B T_{para}/m$$

- Error bars represent T_{para} from fitting. Black points are translation energy calculated from energy partitioning.