Velocity Map Imaging Spectrometer for the Study of Atomic and Molecular Physics in the Gas Phase

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Introduction

Imaging techniques now dominate the study of excited state molecular dynamics and strong field physics. The ability to angle and energy resolve fragments produced via laser induced processes can provide a new viewpoint for the study of molecular fragmentation, strong field ionization and dissociation and Coulomb explosion processes, among others. To this end a new velocity map imaging (VMI) spectrometer specifically designed for the study of highly energetic fragments has been designed and built at the Artemis facility. The chamber contains a molecular beam source and VMI spectrometer that can be configured to collect both ions and electrons with kinetic energies up to 200 eV.

General Description

The atomic and molecular (AMO) physics endstation has been designed to be a versatile chamber for the study of a variety of gas phase targets. The chamber is separated into two sections, a lower chamber which contains a molecular beam source and an upper chamber which contains the VMI spectrometer.

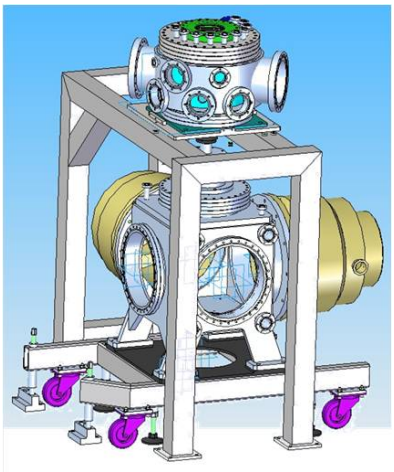

Figure 1: The AMO endstation at the Artemis facility

The source chamber is pumped by two 3200 l/s turbo molecular pumps and contains a continuous molecular beam source. The molecular beam is created by expanding a high pressure gas sample through a 100 μm diameter nozzle. The beam is skimmed at the interface between the source and spectrometer chambers with the skimmer acting to separate the two chambers. The cooling from the supersonic expansion and skimming the beam is sufficient to produce rotationally cold molecular sample. Cooling has been experimentally demonstrated by the impulsive alignment of N_2 molecules produced by the source. The level of alignment achieved was measured via laser Coulomb exploding the molecule and measuring the angular distribution of the resulting fragments.

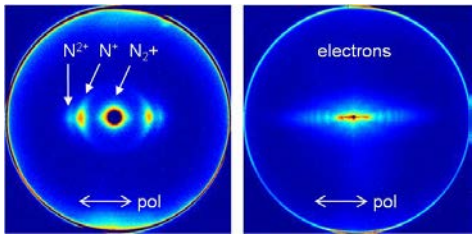

Figure 2: Laser Coulomb explosion a) ion images and b) photoelectron images from impulsively aligned N_2 molecules. The arrows indicate the laser polarization direction

The upper chamber is pumped by a 600 l/s turbomolecular pump maintaining a base pressure of approximately 10^{-9} mbar. The VMI spectrometer follows the three electrode design of Eppink and Parker [1] with the molecular beam entering the spectrometer through a small hole in the repeller plate. Voltages of up to 15 kV can be applied to the VMI optics which allows us to image high energy fragments of up to 200 eV. The spectrometer can be configured to detect electrons or ions. The detector itself consists of a two stage 70 mm imaging quality micro-channel plate, backed by a phosphor screen and CCD camera. The spectrometer is surrounded in a double layer of μ-metal shielding to prevent penetrating magnetic field from altering the trajectories of photoelectrons produced. The imaging detector can be gated such that specific molecular fragments can be imaged exclusively or configured for time of flight detection of ions or electrons.

The AMO chamber can be connected to any of the laser and XUV beam lines available at Artemis with the laser crossing the molecular beam at right angles between the repeller and extractor plates. The ions/electrons are then accelerated collinearly with the molecular beam toward the imaging detector.

The endstation has so far been used to measure energy and time resolved photoelectron images, Coulomb exploding molecular fragments and ion imaging of molecular fragmentation.

Conclusions

The AMO endstation is designed to enable experiments such as studies of the dynamics of aligned molecules, control of electron recollisions, time-resolved photoelectron imaging of excited state molecular processes, and Coulomb explosion imaging of molecular wavepackets. The AMO endstation has been used with the TOPAS and the monochromated XUV beamline and is now available to users. Future development of

the molecular beam source will allow studies on clusters and molecules of biological interest.

Acknowledgements

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References

1. A.T.J.B. Eppink and D.H. Parker. Rev. Sci. Instrum. **68** 3477 (1997).