Redevelopment of the AMO end-station to incorporate a skimmed molecular beam source

Contact *richard.chapman@stfc.ac.uk*

Richard Chapman
Central Laser Facility
STFC Rutherford Appleton Laboratory, UK

Steven Yap
Central Laser Facility
STFC Rutherford Appleton Laboratory, UK

Emma Springate
Central Laser Facility
STFC Rutherford Appleton Laboratory, UK

Cephise Cacho
Central Laser Facility
STFC Rutherford Appleton Laboratory, UK

Phil Rice
Central Laser Facility
STFC Rutherford Appleton Laboratory, UK

Billy Costello
Central Laser Facility
STFC Rutherford Appleton Laboratory, UK

Russell Minns
School of Chemistry
University of Southampton, UK

Introduction

The atomic molecular and optical (AMO) end-station in Artemis is designed for the study of non-adiabatic dynamics in gas phase systems. Using the technique of time resolved photoelectron spectroscopy (tr-PES), the dynamics of a range of systems from molecular alignment to photodissociation can be probed.

The versatility of tr-PES within Artemis is partly down to the ultrafast tuneable laser sources and ultrafast XUV sources. The wide range of energies available as both pump and probe gives access to all changes in a system, be it rotational, vibrational or electronic.

In this paper we describe the implementation of a skimmed molecular beam designed for sample. Our measurements of the gas source show a sub-20 miscrosecnd gas pulse, spatialy confined to a few millimetres.

Technical specification

The AMO end-station consists of two coupled chambers (upper and lower). The lower chamber consists of a gas jet designed by Janssen et. al. [1] that can operate in continuous flow mode or kilohertz pulse mode to produce the gas source. There are two 2800 litres /second turbo pumps used for pumping away excess gas and maintaining a low pressure.

The upper chamber consists of a velocity map imaging (VMI) spectrometer that follows the three-electrode design of Eppink and Parker [2]. It features two micro-channel plates (MCP) working in tandem followed by a phosphor screen as the detector. Voltages up to 15 kV can be applied to the electrodes which allow the detection of ions or electrons with kinetic energies of up to 200 eV.

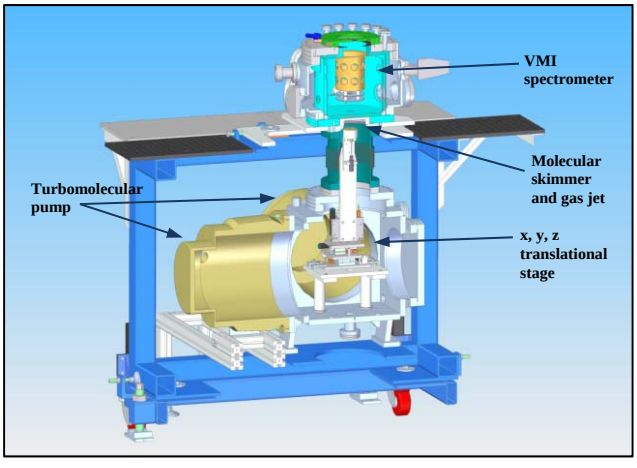

Figure 1 Cutoff diagram of the AMO endstation

Improvements

The main focus of the redevelopment was to improve the gas definition within the focus of the VMI. To do this we used a molecular skimmer in conjunction with the gas jet to produce a differentially-pumped molecular beam. The molecular skimmer was positioned 75 mm below the focus of the VMI. By positioning it close to the focus of the VMI the gas density in the molecular beam would still be high enough for signals to be

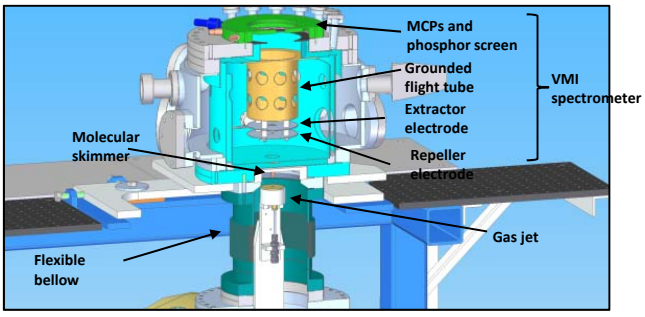

Figure 2 Detailed components in the AMO end-station

detected but also in a position where the top and bottom chambers could be isolated to prevent a higher than necessary background gas level.

The molecular skimmer was placed in line with the centre of the VMI and the gas jet was mounted on a XYZ stage to allow accurate alignment with the molecular skimmer. A hard stop was inserted to prevent the jet being driven through the molecular skimmer.

A gated bypass was also inserted to allow pressure equalisation during pump down and let up procedures that could be isolated during experiments.

Molecular beam characterisation

A series of tests were carried out to characterise the effect of the changes made to the system. Initially the gas jet was aligned with the molecular skimmer by looking for maximum transmission of gas through the skimmer and hence the maximum pressure achieved in the upper chamber.

In order to characterise the pulse width of the gas jet the fundamental laser (790 nm, 1 kHz) was focused into the interaction region to ionise an argon target. Using a photodiode to detect the laser pulses and a delay generator to offset the gas jet timing the pulses could be synchronised.

The VMI was set up to measure the generated argon ions as a function of delay between the laser and gas jet. The resulting graph in figure 3 shows that a molecular beam with a length of 17.9 μs was created which corresponds to approximately 2.5 mm. Although this is not as short as the length quoted in the manual of the gas jet (7 μs) [1] it is a significant step forward as a defined gas pulse was not previously observable.

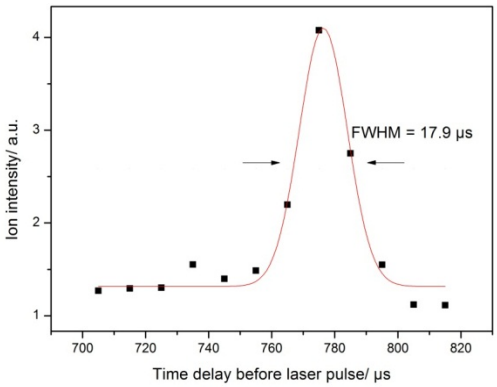

Figure 3 Graph of ion intensity against time delay for a gas jet triggered before arrival of laser pulse. A gaussian fit (red line) shows the full width half maximum (FWHM) duration of the molecular beam.

Spatial imaging

The next step in testing was to image the spatial distribution of the electrons. In previous experiments using XUV pulses to ionise the gas, it had been possible to see electrons generated over tens of millimetres with similar probabilities due to the long Raleigh range and poor confinement of the target. This is the key factor that limited the resolution of the detector.

The VMI was switched from ion to electron detection and the delay was set to 775 μs for maximum signal as observed previously. The repeller electrode and the extractor electrode in the VMI spectrometer were set at -2000 V and -1950 V respectively to utilise the spatial image mode.

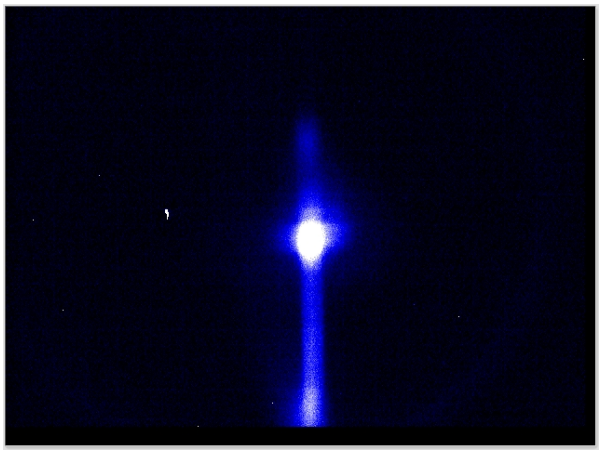

Figure 4 Spatial image of argon molecular beam obtained using 800 nm laser pulses.

Figure 4 shows the resulting electron distribution at the focus of the VMI. The clearly defined region in the centre shows that there is a defined area of high gas density. By translating the lens 10 mm in either direction a sharp drop off in signal intensity is observed demonstrating that the background gas levels in the chamber are very low.

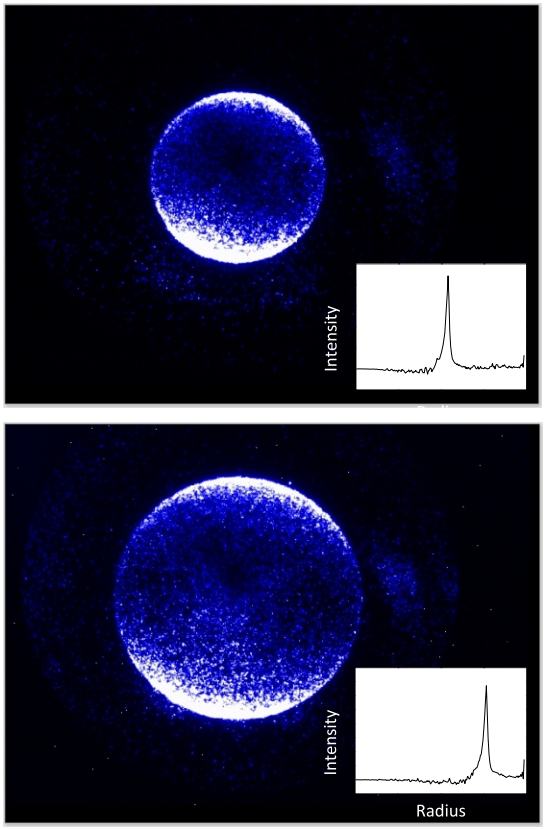

Figure 5 Velocity mapped image of argon obtained using 21 eV (top) and 27 eV (bottom) XUV photons. Inset: Radial spectrum obtained via the Polar Onion Peeling algorithm.

Velocity map imaging

The final step in the testing was to look at the ionisation using the high harmonics generated in Artemis. The end-station was coupled to the XUV monochromator beamline and the VMI was set up in velocity imaging mode (repeller -2000V, extractor -1450V). The XUV was focused into the VMI to ionise the same argon target. Using either harmonics at 21 eV or 27 eV the argon could be directly ionised and the resulting electron spread captured.

The data shown in figure 5 was captured with an exposure time of 66 ms for 21 eV harmonics and 1 s for 27 eV harmonics. The images captured were of high enough quality to be inverted using the polar onion peeling method. The results are also shown in figure 5.

Conclusions

The redevelopment of the AMO end-station has been shown to have produced a sub-20 microsecond gas pulse, spatially confined to a few millimetres. The VMI has also been shown to operate with good signal to noise with the modifications. These improvements should significantly increase the energy resolution of future experiments with the AMO end-station.

References

1. M. H. M Janssen *et al*., *Rev. Sci, Instrum*. **80**, 113303 (2009)

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