VMI

Velocity Map Imaging with ASI TPX3CAM Hybrid Pixel Detector

Application Highlights

- **Resolve multiple mass ions in one measurement**
- **Time-of-Flight and position of all ions of every shot**
- **Full momenta can be obtained based on single event detection and analysis**
- **Suitable for MHz repetition rates lasers**
- **Easy synchronization of multiple detectors for coincidence momentum imaging**

Still using frame-based CCD or CMOS camera for your VMI research?

Velocity map imaging (VMI) research often uses a conventional frame-based CCD or CMOS camera, which can only obtain integral images within a fixed time window. This means it cannot separate ions with different masses within one frame. Fast-gating with such cameras allows the selection of ions of specific mass, or slice imaging of the Newton sphere (Figure 1). However, this has clear drawbacks.

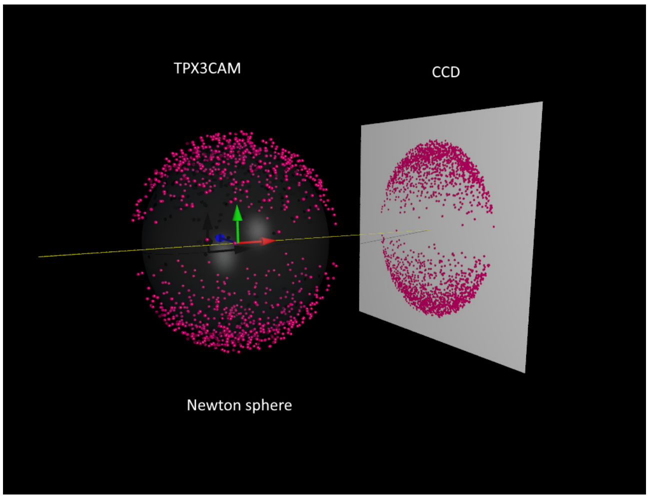

Figure 1. Newton Sphere of ion fragments generated in photofragmentation. A CCD camera records 2D integral images of the Newton Sphere. Replacing the CCD camera with ASI TPX3CAM, one can record event list (X, Y, TOF) for all ions and thus do a direct measurement of the Newton Sphere

Gating means that all information of other ions with different masses is lost, while this information is very important for ion-ion coincidence momentum or covariance imaging. In fact, obtaining full momenta of all single electrons or ions is simply impossible with a frame-based camera. To retrieve the 3D Newton sphere, or slices of it, from a 2D image, algorithmic methods such as Abel inversion can be

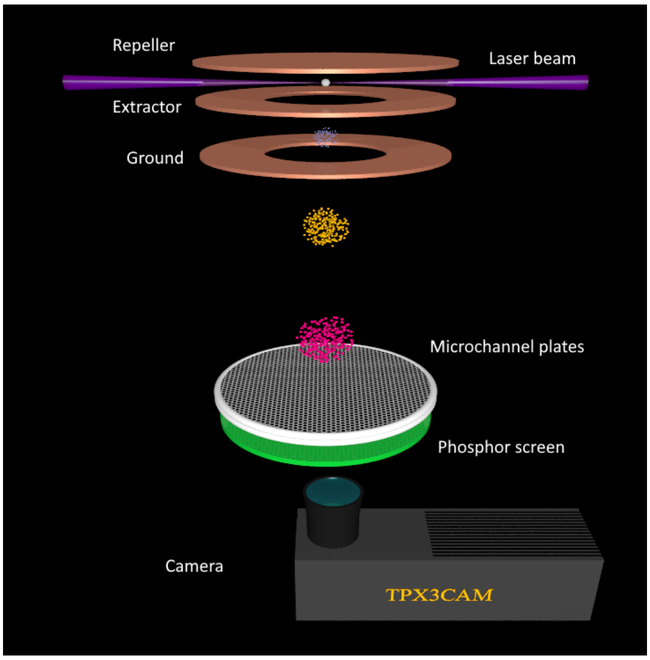

Figure 2. Typical velocity map imaging setup. The VMI setup normally consists of electrostatic lenses, microchannel plates (MCPs), phosphor screen, e.g. P46, P47, etc., and an optical camera. Here the CCD camera has been replaced by a TPX3CAM detector.

used. This process can however bring additional artifacts and noise to the reconstructed images. Also, with frame-based cameras the repetition rate of the sequential measurements is limited to kHz rates due to the frame rate limitations of sensitive cameras.

Essentially, because the cameras collect images, they do not deliver what is of real interest: ion or electron events. They generate a lot of useless data and most frames are filled with background or read-out noise. TPX3CAM can resolve this by detecting the time-of-flight and location of all charged fragments.

How ASI TPX3CAM can accelerate your VMI research!

TPX3CAM is an event-based detector that enables researchers to measure the arrival of individual ions and electrons with 1.56 ns resolution. This significantly changes the way VMI can be performed.

TPX3CAM is an easy drop-in replacement of the conventional CCD or CMOS cameras in VMI (Figure 2). The data output of a TPX3CAM is a list of events. Each event has a X, Y and TOF value and each event corresponds to the arrival of an ion or electron. This X, Y position and TOF information allows the detection of all dissociative ions, meaning that full momenta of ions in the fragmentation dynamics of the photochemical reaction can be calculated (see Figure 3). This in turn enables researchers to do direct slice imaging of the velocity distribution of specific ions. See an example given in Figure 4.

The fast, event-driven readout allows the TPX3CAM to work with extremely high repetition rate laser pulses, up to 10 MHz, not limited by a kHz frame rate such as CCD camera's. Timestamps of each laser pulse can be recorded directly in the data stream of the TPX3CAM using an LVTTL input, enabling easy calculation of TOFs of corresponding ions.

Other applications can also benefit from the advanced position- and time- sensitive imaging detector - TPX3CAM. These applications include coincidence momentum imaging (CMI), mass spectrometry imaging, and atomic probe tomography. For CMI, one can easily set up two TPX3CAMs in the opposite direction of a reaction microscope. Multiple TPX3CAMs can be clock synchronized to ps levels and used to detect electrons and ions simultaneously.

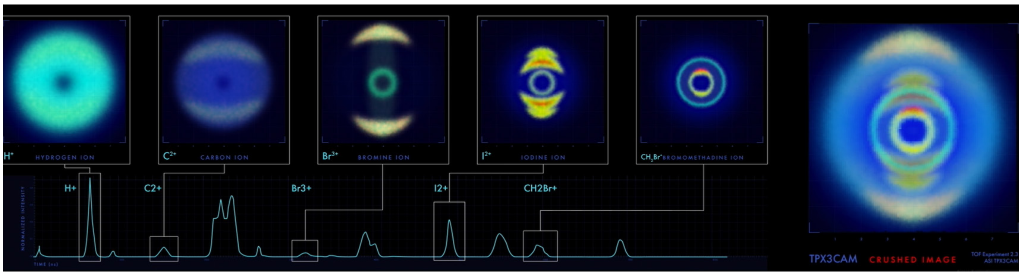

Figure 3. 2D image for each mass ions with TOF information can be reconstructed in any time window.

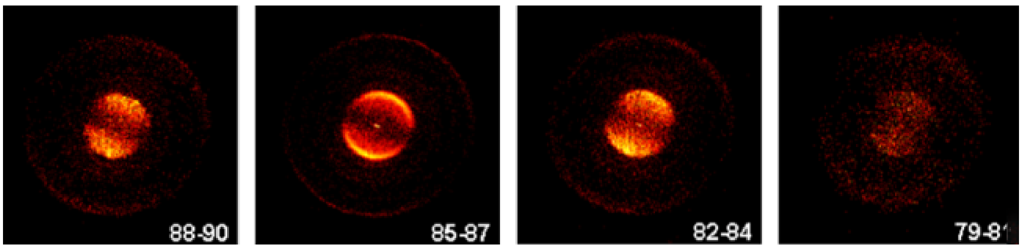

Figure 4. Images of slices through the NO+ velocity distribution in photodissociation of NO2 at 451.64 nm. The time bin used here is 12.5 ns. The graph is adapted from the reference Rev. Sci. Instrum. 81, 103112 (2010).

Summary

Breaking the limits of conventional CCD and CMOS cameras, ASI's fast optical time-stamping detector – TPX3CAM, has proved useful in various electrons/ions imaging applications. The TPX3CAM will continue to bring new opportunities for scientists by facilitating advanced particle imaging research.
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