The Pixel Imaging Mass Spectrometry Sensor - Functionality, Performance, and a variety of Applications

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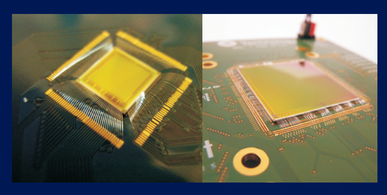
The Pixel Imaging Mass Spectrometry sensor (PImMS sensor) - a versatile fast Imaging Sensor -

PImMS 1 Camera



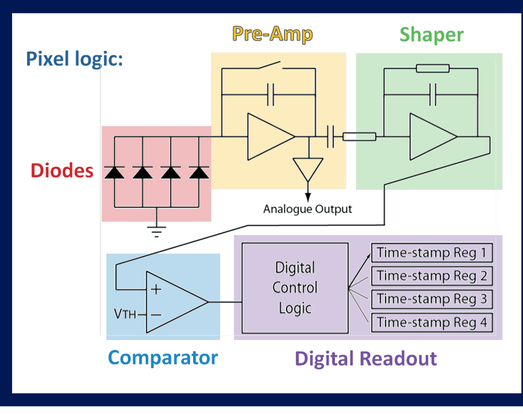
Developed in collaboration with Oxford Physics and the Rutherford Appleton Laboratory [1-3].

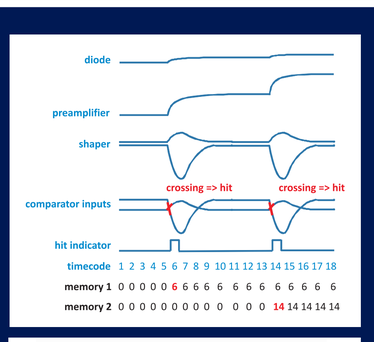
- Event counting device:
  > Ion event time stamp: x, y, t
  > saves only relevant data
  > detects any mass
  > not restricted to pre-selected masses
  > up to 4 time stamps per pixel

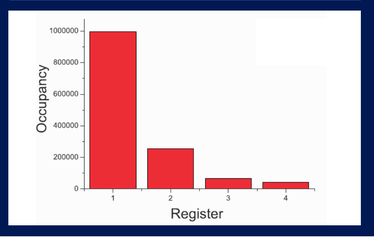
- PImMS1: 72 x 72 pixels
- PImMS2: 324 x 324 pixels
- 4 registers in each pixel for multi event detection
- time code width 12.5 ns (down to 6.25 ns)
- maximum repetition rate up to 500 Hz
- based on INMAPS-CMOS technology

Advantages over other time-stamping devices:
- multiple registers per pixel >> no data is lost due to 'shadowing' by earlier events
- can replace CCD camera in existing MCP/phosphor/CCD detection systems

PImMS 2 sensor: currently in testing; 324 x 324 pixels, 6.25 ns timing precision, and a more uniform sensitivity over the sensor



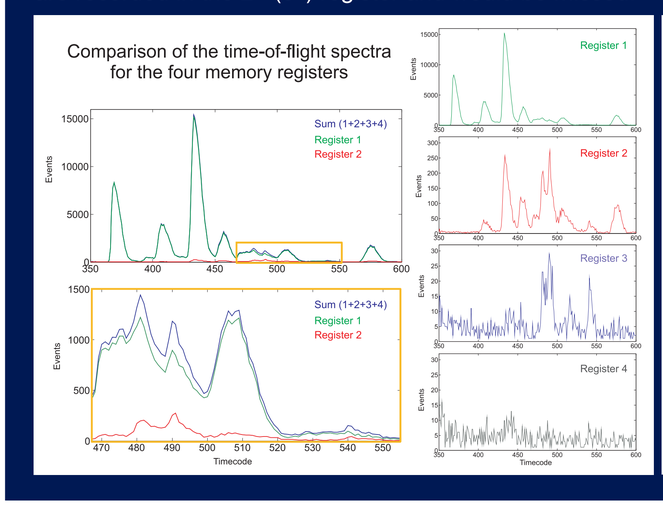


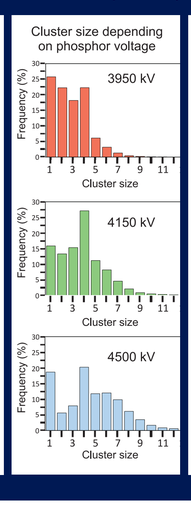


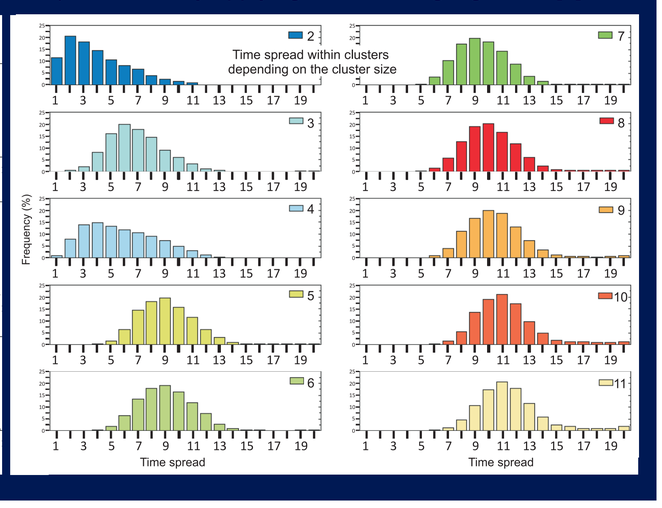
Characterisation and Performance

Multiple memories per pixel are important: some of the ions are recorded in the 2nd (3rd) register and would be missed.

Cluster analysis: clusters can be used to enhance spatial and temporal (mass) resolution by applying a centroiding algorithm [4].



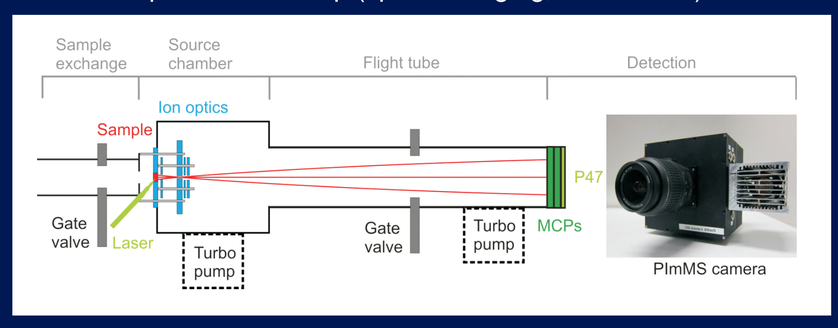




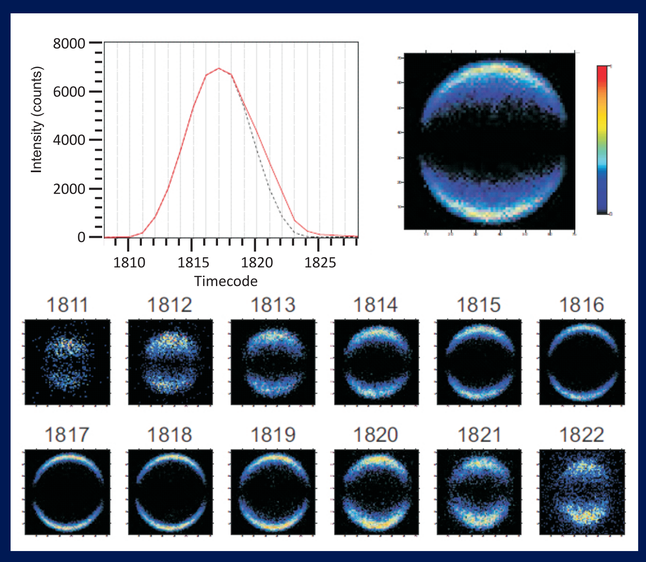
Applications

(1) 3D Velocity-map imaging (VMI)
(2) Photoelectron - multiple-photoions coincidence VMI
(3) Spatial imaging mass spectrometry in microscope mode
(4) Imaging of molecular structure (and follow structural changes in real-time) using Coulomb-explosion VMI (and fs laser pulses)

Experimental setup (spatial imaging; VMI similar)

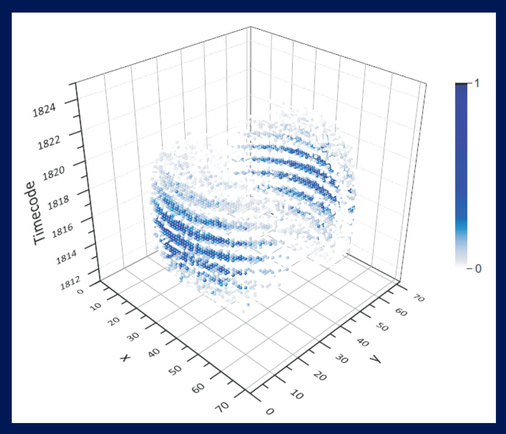


(1) Velocity-Map Imaging: 3D Newton Spheres



Photoinduced dissociation and ionisation of EtI at 245.30 nm (resonant transition) [4]:

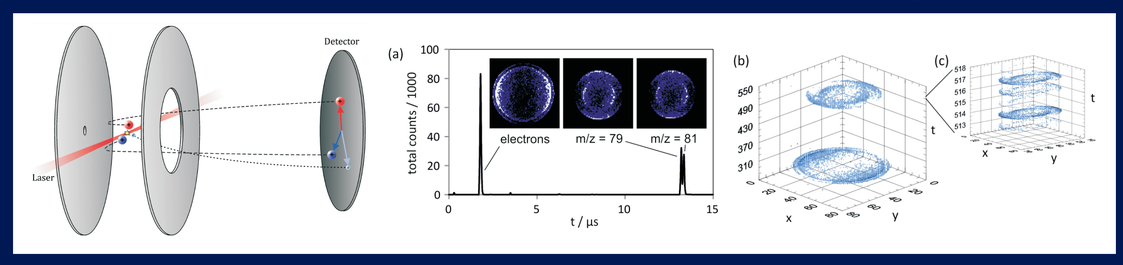
$$EtI \xrightarrow{h\nu} Et + I^* \xrightarrow{2h\nu} Et + I^{**} \rightarrow Et + I^+$$



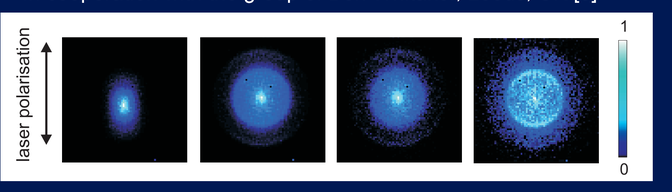
(2) Velocity-Map Imaging: PEPICO on a single detector using pulsed extraction

The pulsed extraction technique to image both electrons and ions on the same detector within the same acquisition cycle.

Time-of-flight spectrum, and electron and ion images of Br_2, with the two isotopes resolved, and x, y, t - representation (right).



In cooperation with the group of Ben Whitaker, Leeds, UK [5]

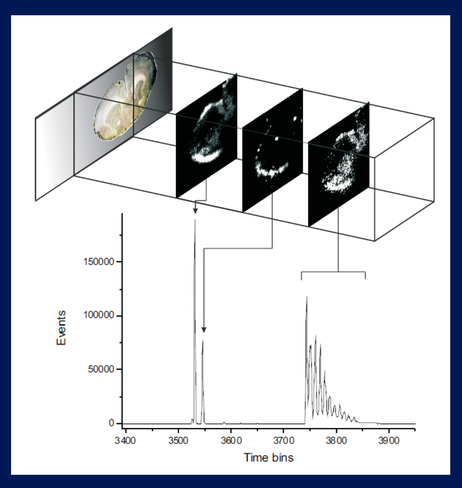


Dissociative ionisation of No_2 at 387 nm: (from left to right)
- ion image of NO^+
- total electron image
- electrons in coincidence with NO^+
- electrons in coincidence with NO_2^+

(3) Spatial Imaging

Microscope-mode mass imaging of surfaces

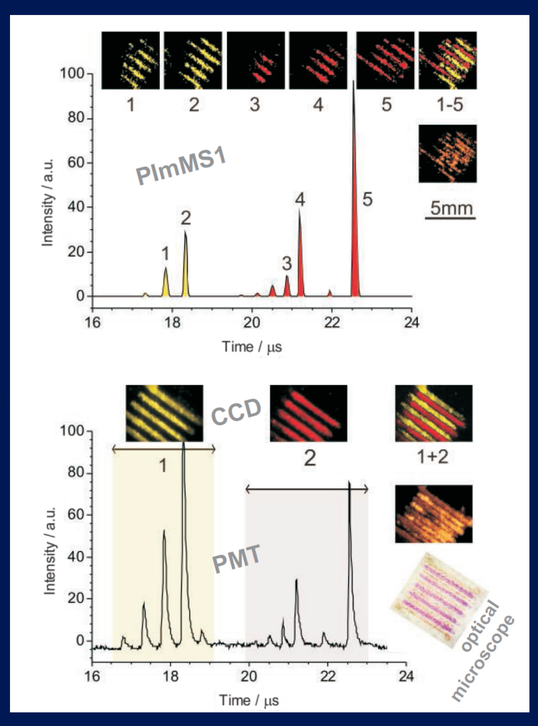
Right: Alternating stripes of two dyes (Auramine O and Rhodamine 6G) demonstrate multi-mass imaging [6]
Below: Tissue imaging



Performance:

Spatial resolution: < 20 µm

Mass resolution: > 2000 m/Δm

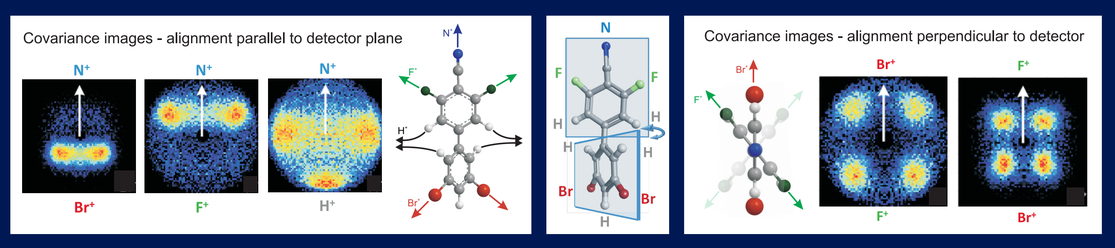


(4) Imaging of Molecular Structure and Motion

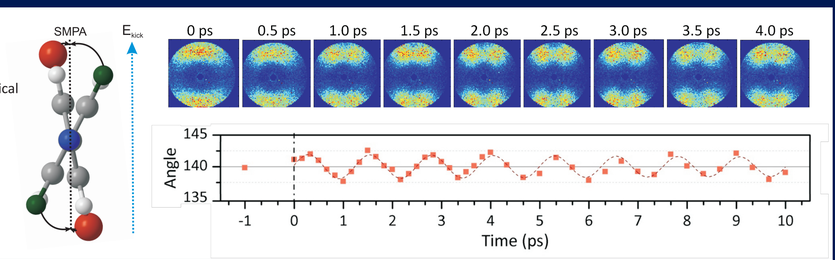
Coulomb explosion velocity-map imaging & ion-ion covariance analysis[7,8]

>> See also Poster We-T10-10:

Femtosecond Time-Resolved Imaging of Torsion in a Chiral Molecule using PImMS
L. Christensen, C. S. Slater, A. Lauer, S. Blake, J. H. Nielsen, M. Brouard, H. Stapelfeldt



1. Alignment:
   Nd:YAG laser
   (1064 nm, 10 ns, 20 Hz)
   polarisation horizontal/vertical/elliptical
2. Kick-Pulse (optional):
   Ti:Sa laser
   (800 nm, 130 fs)
   polarisation vertical
3. Coulomb-explosion probe pulse:
   Ti:Sa laser
   (800 nm, 30 fs)
   polarisation vertical



[1] J. J. John, M. Brouard, A. Clark, J. Crooks, E. Halford, L. Hill, J. W. L. Lee, A. Nomerotski, R. Pisarczyk, I. Sedgwick, C. S. Slater, R. Turchetta, C. Vallance, E. Wilman, B. Winter, and W. H. Yuen, *JINST* **7**, C08001 (**2012**).
[2] A. T. Clark, J. P. Crooks, I. Sedgwick, R. Turchetta, J. W. L. Lee, J. J. John, E. S. Wilman, L. Hill, E. Halford, C. S. Slater, B. Winter, W. H. Yuen, S. H. Gardiner, M. L. Lipciuc, M. Brouard, A. Nomerotski, and C. Vallance, *J. Phys. Chem. A* **116**, 10897 (**2012**).
[3] I. Sedgwick, A. Clark, J. Crooks, R. Turchetta, L. Hill, J. J. John, A. Nomerotski, R. Pisarczyk, M. Brouard, S. Gardiner, E. Halford, J. W. L. Lee, M. L. Lipcius, C. S. Slater, C. Vallance, E. Wilman, B. Winter, W. H. Yuen, *NEWCAS* (IEEE) 497 (**2012**).
[4] S. Blake, *Applications of Fast Imaging Detectors in Velocity-Map Imaging*, (Master Thesis) University of Oxford (**2013**).
[5] I. Wilkinson, I. A. Garcia, B. J. Whitaker, J.B. Hamard, and V. Blanchet, PCCP 12, 15766 (**2010**).
[6] M. Brouard, E. Halford, A. Lauer, C. S. Slater, B. Winter, W. H. Yuen, J. J. John, L. Hill, A. Nomerotski, A. Clark, J. Crooks, I. Sedgwick, R. Turchetta, J. W. L. Lee, C. Vallance, and E. Wilman, *Rev. Sci. Instrum.* **83**, 114101 (**2012**).
[7] J. L. Hansen, J. H. Nielsen, C. B. Madsen, A. T. Lindhardt, M. P. Johansson, T. Skrydstrup, L. B. Madsen, H. Stapelfeldt, *J. Chem. Phys.* **136**, 204310 (**2012**).
[8] J. L. Hansen, L. Holmegaard, L. Kalhøj, S. L. Kragh, H. Stapelfeldt, F. Filsinger, G. Meijer, J. Küpper, D. Dimitrovski, M. Abu-samha, C. P. J. Martiny, L. B. Madsen, *Phys. Rev. A* **83**, 023406 (**2011**).

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