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INSTRUMENTS

# Making the Invisible Visible

## TPX3Cam

### A fast optical camera for nanosecond photon time stamping


"We use the TPX3Cam for measurements of electrons and ions in our velocity map imaging apparatus. The ns time resolution and data acquisition rate allow us to make measurements in ways that were not possible before. We are very happy with the camera performance."

Thomas Weinacht, Professor at the Department of Physics and Astronomy,
Stony brook university, USA

# TPX3Cam

## Technology

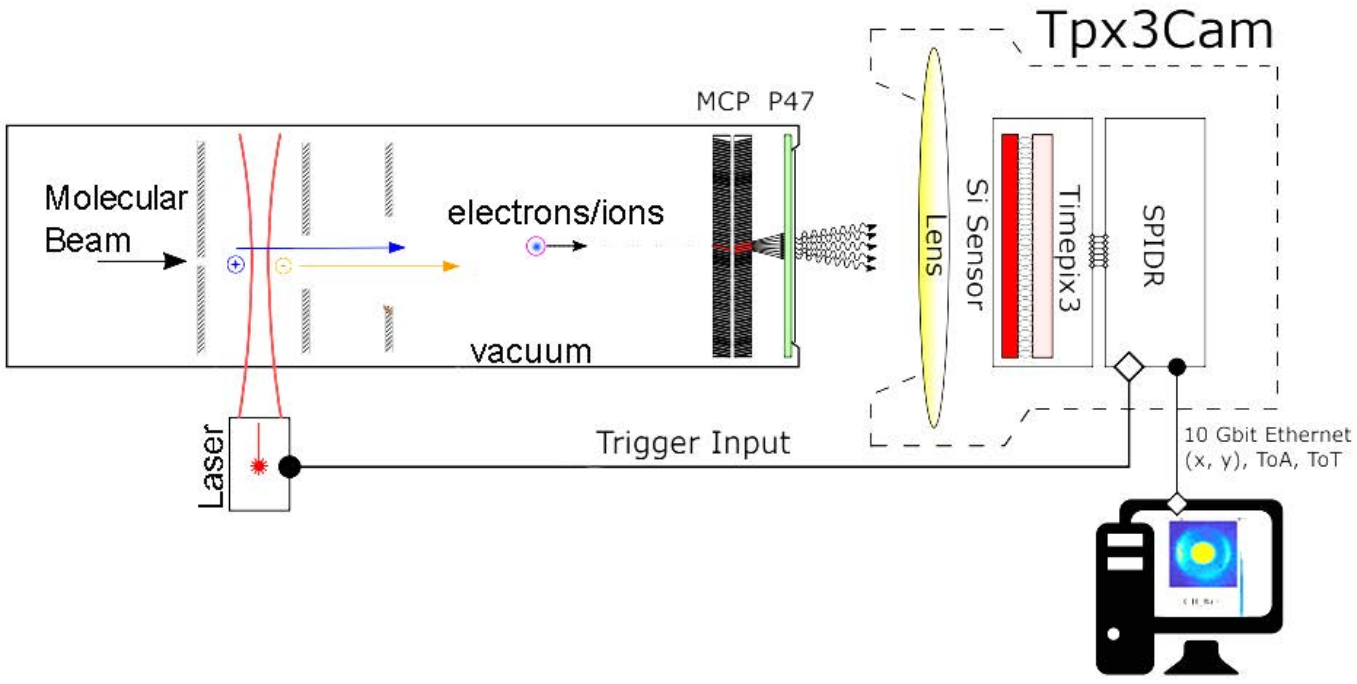
The TPX3Cam is a fast optical camera for time stamping of optical photons. It is based on a new silicon pixel sensor, which in combination with the Timepix3 ASIC and readout, is suitable for a wide range of applications which require time-resolved imaging of electrons, ions or single photons.

The TPX3Cam can be easily integrated both in table-top lab setups, as in synchrotron or free-electron-laser environments.

## Benefits of TPX3Cam

- Increased light sensitivity silicon sensor
- Wave length range: 400 - 1000 nm
- Per pixel simultaneous detection of time (ToA) and intensity (ToT)
- Time resolution 1.6 ns, effective frame rate > 500 MHz
- Lossless, data driven readout up to 80 Mhits/s
- Flexible optical design outside of vacuum

Image below: TPX3Cam is able to simultaneously image and time-stamp light flashes of more than 1000 photons with high quantum efficiency in the 400 to 1000 nm wavelength range. It can efficiently register ions impinging on an MCP (micro-channel plate) in the VMI (velocity map imaging) configuration. The MCP is coupled to a fast P47 phosphor, which produces light flashes in response to ions hitting the MCP. The TPX3Cam, placed outside of the vacuum, can detect light flashes from the phosphor.
Adapted from Zhao et. al, Review of Scientific Instruments 88, 113104 (2017)




"In TPX3Cam all individual pixels function independently and are able to time stamp incident 'events'. This transforms the imaging sensor into an array of fast digitizers with both spatial and temporal resolutions acting in parallel so multiple ion species can be registered simultaneously allowing for coincidence and covariance analyses."

Dr. Andrei Nomerotski
Brookhaven National Laboratory, USA

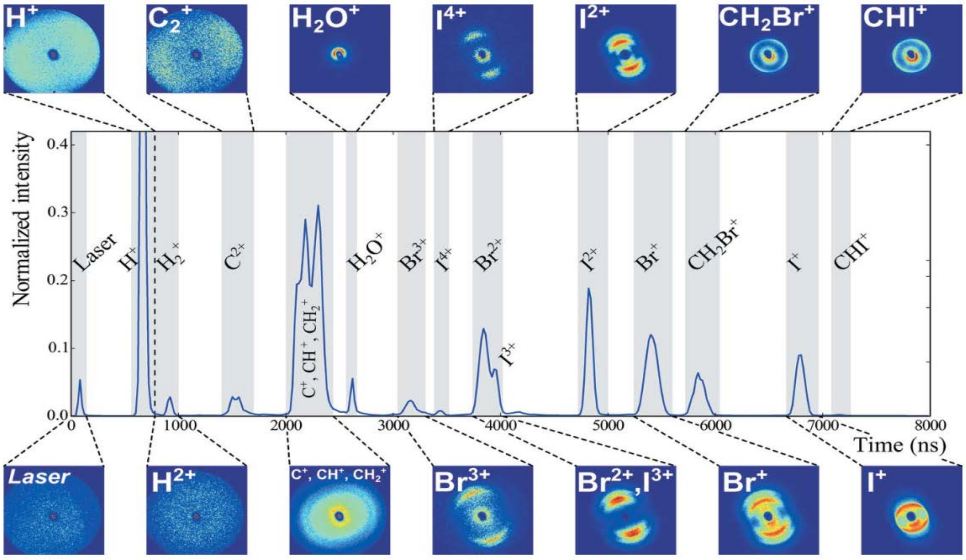
# Applications

## Ion and electron imaging

Applications of TPX3Cam include spatial and velocity map imaging of ions in time-of-flight mass spectroscopy; coincidence imaging of ions and electrons, and other time-resolved types of imaging spectroscopy. TPX3Cam is able to detect and time-stamp ion hits with 1.6 ns timing resolution, thus making it possible to record ion momentum images for all fragment ions simultaneously and avoiding the need to gate the detector on a single fragment.

This single detector design is simple, flexible, and capable of highly differential measurements.

Image below shows ion TOF mass spectrum of $CH_2IBr$ recorded with TimepixCam, a previous model of the TPX3Cam, at the FLASH light source at the German Synchrotron, Hamburg after strong-field ionization with an intense laser pulse along with the camera images for each of the peaks in the TOF spectrum.
Adapted from M.Fisher-Levine et al, J. Synchrotron Rad. (2018) 25, 336-345.




## Single photon imaging

The intensified version of TPX3Cam can be single photon sensitive. In this configuration the camera is employed in combination with an off-the-shelf image intensifier. The applications include the wide-field time-correlated single photon counting (TCSPC) imaging, phosphorescent lifetime imaging and any applications requiring time-resolved single photon imaging.

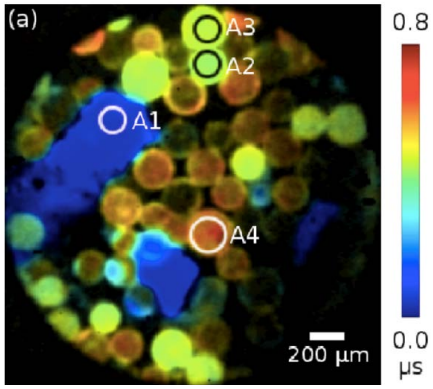



Image (a): Lifetime images of beads infused with different Ir compounds and fluorescent plastic acquired with TimepixCam, a previous model of the TPX3Cam.

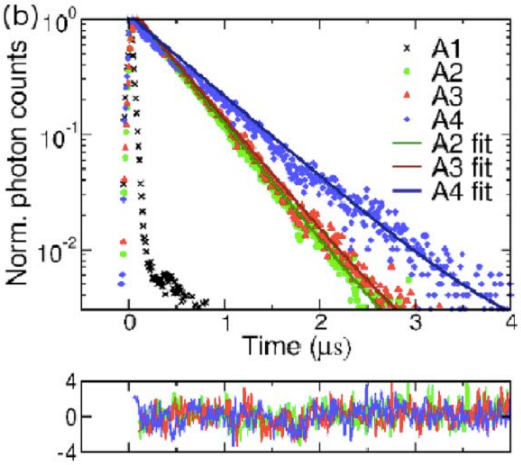



Image (b): Intensity as a function of time (phosphorescence decays) for areas A1-A4 indicated in (a), with monoexponential fits to the phosphorescence decays and residuals of the fits.
Adapted from L. M. Hirvonen et al, Rev. Sci. Instrum. 88, 013104 (2017).

# Specifications

## TPX3Cam specifications

| | |
|---|---|
| Sensor | |
| Material | silicon with enhanced light sensitivity |
| Wave length range | 400 - 1000 nm |
| Detection limit | ~1000 photons per pixel hit |
| Optics | |
| Sensor active area | 14.1 x 14.1 $mm^2$ |
| Type | C-mount |
| Minimal distance lens to sensor | 42 mm |
| Imaging ASIC | |
| Type | Timepix3 |
| Pixel pitch | 55 µm |
| # of pixels | 256 x 256 |
| # of thresholds | 1 |
| Throughput | up to 80 Mhits/s for 10 Gb/s<br>up to 15 Mhits/s for 1 Gb/s |
| Read-out dead time | Dead time zero, within allowed throughput |

| | |
|---|---|
| Time resolution | 1.6 ns |
| Effective frame rate | > 500 MHz |
| Pixel hit dead time | ~1 µs |
| Read-out mode | Data driven, simultaneous time and intensity by per pixel ToA and ToT detection |
| Other | |
| Computer interface | 1 Gb/10 Gb Ethernet |
| External shutter control | Yes |
| External signal time stamping | 260 ps |
| Weight | 2.2 kg |
| Dimensions (l x w x h) | 28.5 x 80 x 90 $cm^3$ |
| Cooling | Air |
| Acquisition software | GUI for Windows/ Linux/Mac |

## Amsterdam Scientific Instruments

We develop and supply hybrid pixel detectors for a wide range of applications such as X-ray, electron microscopy and mass spectrometry imaging. Our innovative imaging solutions open up new opportunities in various industries by significantly sharper and faster imaging.

Visit our website for selected TPX3Cam publications:
www.amscins.com/publications

The technology can be used in multiple applications such as:

- Energy resolved X-ray
- Computed tomography
- Fast product-line X-ray inspection
- Electron microscopy
- Mass spectrometry
- Single photon imaging
- Ion and electron imaging

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