Imaging Photon Camera with High Spatiotemporal Resolution

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PHOTONIS
SCIENTIFIC DETECTORS

Abstract:

Photon counting detectors with high spatiotemporal resolution are key tools of imaging techniques where picosecond timing and micrometer imaging are required, for example in time resolved single molecule imaging. PHOTONIS' Imaging Photon Camera (IPC) is a wide field of view (18 mm active area) system able to detect individual photons within resolution of 100 ps in time and 40 µm FWHM in position. The Imaging Photon Camera consists of a dual microchannel plate (MCP) tube equipped with a 22 mm cross strip (XS) anode and specially designed high speed electronics that achieve global count rates up to 5 MHz.

Camera Overview:

The microchannel plate (MCP) tube (Figure 1) is enclosed in an air tight aluminum housing with thermoelectric coolers and temperature sensors (Figure 2). A C-type mount allows attachment of lens, a microscope phototube or any desired optics.

Figure 1: MCP Tube with dual MCP and 22 mm cross strip anode.

Figure 2: MCP Tube mounted in aluminum housing.

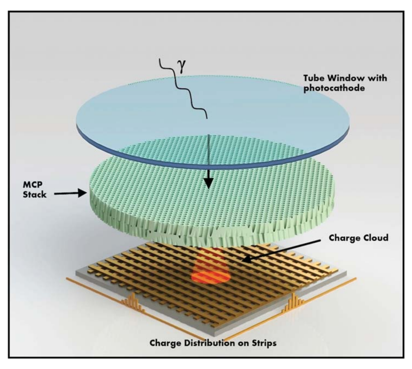


Figure 3: Electrons detected by XS anode.

Incoming photons are converted into electrons by the photocathode and then amplified by a pair of MCPs. The electron cloud is detected by several strips in the XS anode (Figure 3). [1]

New Hi-QE Photocathodes:

The Dark Count rate of the new PHOTONIS Hi-QE S20 photocathodes is extremely low, 20-30 cps/cm² compared to conventional S20 photocathodes, with 1000-2000 cps/cm². [2]

Although the GaAs has a higher QE than the Hi-QE Red ,the dark count rate is also higher for this cathode. Cooling dramatically reduces the dark count rate of all photocathode types (Figure 4).

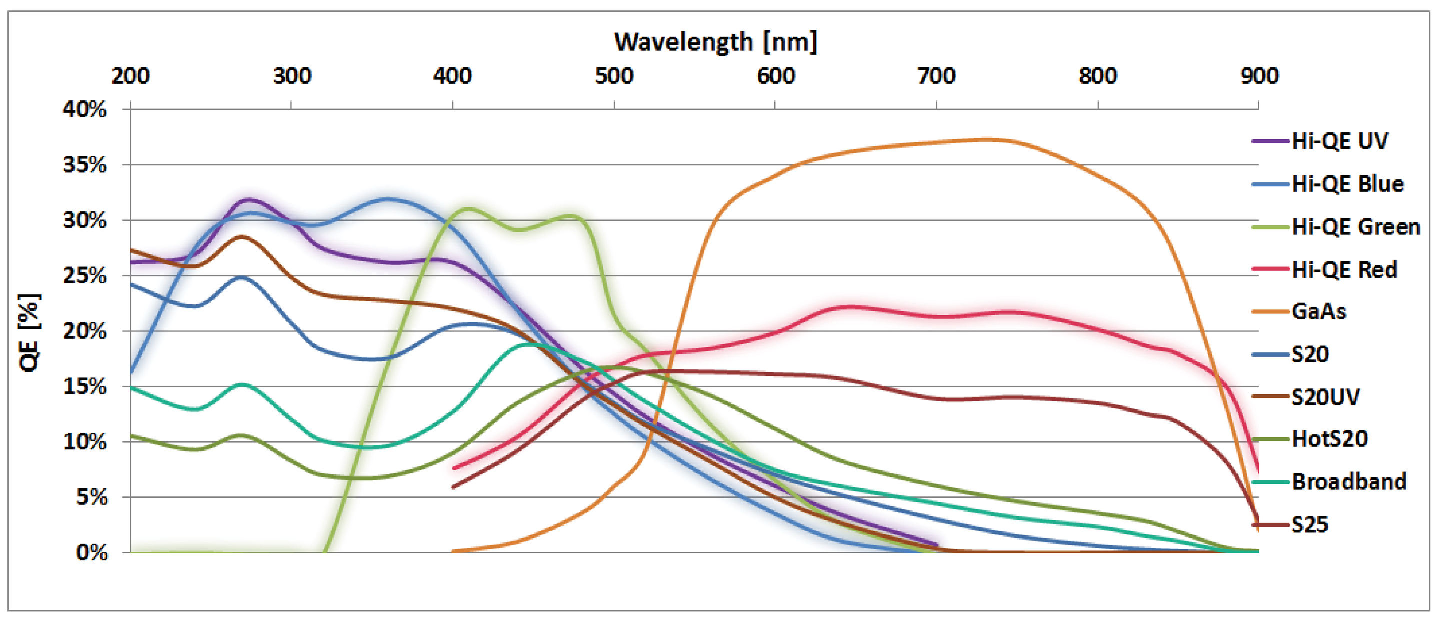


Figure 4: QE Curves show for PHOTONIS' available photocathodes, designed for use in scientific applications.

Detector Configuration:

The photon counting detector is a stack of two microchannel plates in chevron configuration, with 6 µm pore and 80:1 length to diameter channel ratio, allowing electron gains between 10^4 and 10^7. The local count rate, which depends on the MCP recharge time, is ~10 kHz over a 100 µm area.

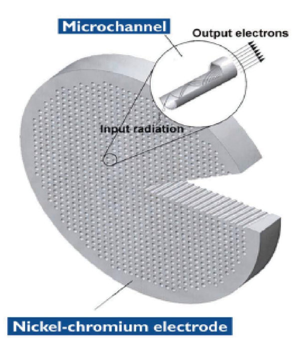
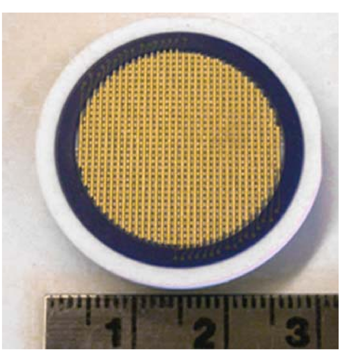


Figure 5 (left): Operational diagram of a Microchannel Plate (MCP).

Figure 6 (right): A photograph of the 22 mm Cross Strip (XS) anode.



Parallel Cross Strip Electronics:

The Parallel Cross Strip Electronics digitize events in neighboring strips of the XS anode that exceed a threshold (Figure 7). [3]

The ADC sampling frequency is 50 MHz. For each photon the X and Y position are calculated by center of gravity of the charge distribution in the X and Y axis. The spatial resolution in X and Y direction is the same and about 40 µm FWHM.

Figure 7: Parallel Cross Strip Electronics process the signals.

A double sampling TDC measures the time between the trigger pulse (a laser) and the detected event. The timing can be measured from the back of the MCP stack if 100 ps resolution is required (Figure 8).The electronics can process up to 5 MHz input event rates.

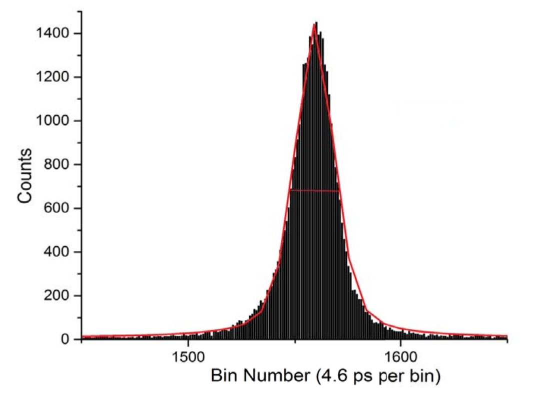


Figure 8: Temporal Resolution shows FWHM at 98 ps.

Acquisition Software and GUI:

For each photon the X and Y coordinates, the pulse height and the coincidence time are transferred to a computer through a 1 gigabit/s Ethernet link. The real time image is generated and important parameters are derived and displayed (Figure 9).

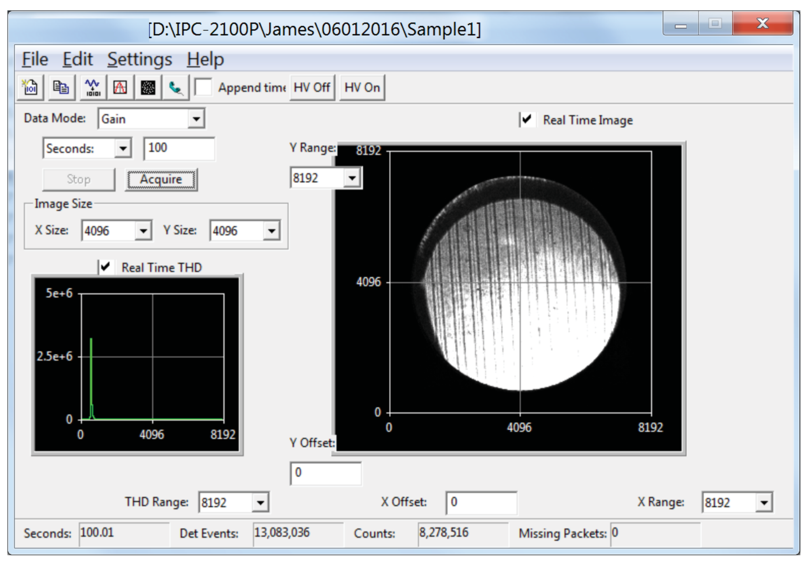


Figure 9: Graphical User Interface provides a real time image with relevant parameters.

The first PHOTONIS IPC, installed at the National Institute of Standards & Technology (NIST), is currently being commissioned in a new single-molecule super-resolution fluorescence lifetime imaging microscope at the Center for Nanoscale Science and Technology at NIST.

Summary and outlook:

Developed by PHOTONIS, the IPC photon counting system is characterized by a unique combination of capabilities: wide field of view, single photon counting, no read out noise, high spatial and temporal resolution. The system has ~100 picosecond timing and ~40 µm spatial resolution. Newly introduced high quantum efficiency photocathodes with ultra low noise additionally boost the IPC performance (Figure 10).

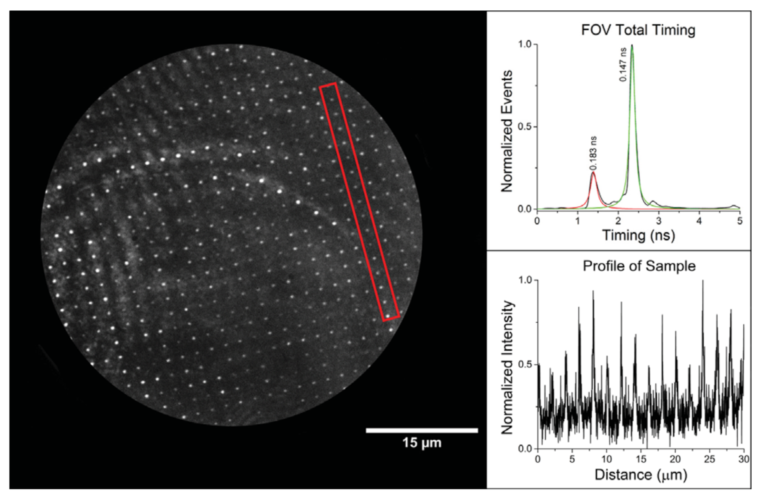


Figure 10: Actual Image from the IPC camera (Courtesy: NIST, 2016). The bright spots are aluminum nanodisks with diameter 500 nm and height of ~30 nm. They are separated by 2 microns and repeat in each direction. The light collected from the sample is the back scattered light from the nanodisks.

References:

[1] Siegmund OHW, Vallerga JV, Tremsin, McPhate J, Welsh B. *Optical Photon Counting Imaging Detectors with Nanosecond Time Resolution for Astronomy and Night Time Sensing*. Advanced Maui Optical and Space Surveillance Technologies Conference Proceedings, p. E77 (2011).

[2] Orlov DA, DeFazio J, Duarte-Pinto S, Glazenborg R, Kernen E. *High Quantum Efficiency S-20 Photocathodes in Photon Counting Detectors,* JINST 11 (2016) C04015.

[3] Siegmund OHW, Tremsin AS, Vallerga JV, Hull J (2001) *Cross Strip Imaging Anodes or Microchannel Plate Detectors.* IEEE Trans Nucl Sci 48:430–434.