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Time-stamping and counting of single photons using fast camera

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Time-stamping and counting of single photons using fast camera

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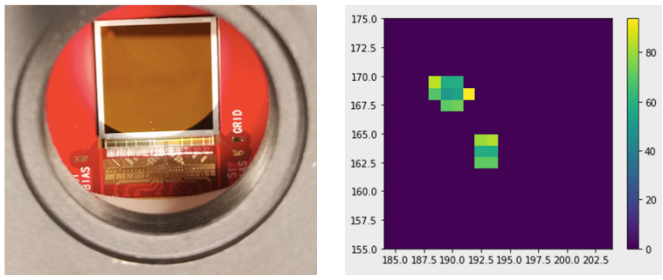
Abstract— **I will discuss fast optical cameras based on the back-illuminated silicon sensor and Timepix3 ASIC. The sensor has high quantum efficiency, and the chip provides nanosecond scale time resolution and data-driven readout with 80Mpix/sec bandwidth. The intensified version of the camera is single photon sensitive and since recently has been used for registration of single photons in a variety of quantum information science and quantum imaging experiments as well as for other applications. We briefly review the camera and describe recent experiments with a Hong-Ou-Mandel interferometer to characterize its photon counting capabilities.**

Keywords — Tpx3C, single photons, photon counting, Hong-Ou-Mandel interferometer

I. Tpx3Cam Fast Camera

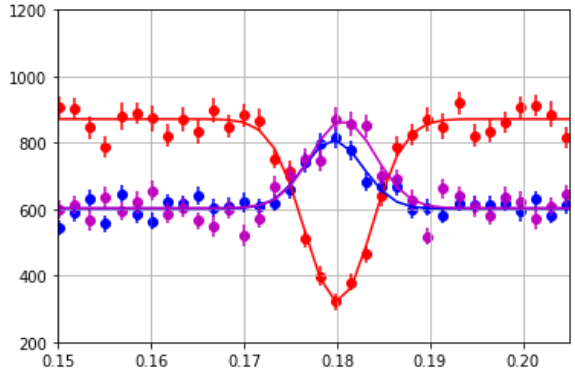
Single photons are able to travel long distances without changing their quantum state and, therefore, are important carriers of quantum information, which can be easily produced in well-defined states and manipulated. Imaging these photons gives access to multi-dimensional information and enable scaling opportunities. In this contribution we discuss a novel fast camera, which provides simultaneous measurement of spatial and temporal information for single photons.



To achieve this, an imaging device, Tpx3Cam, which allows time-stamping of incident photons with 1.6 ns time resolution[1], was coupled to an image intensifier with a fast P47 scintillator. Tpx3Cam consists of a specialized silicon sensor, bump-bonded to Timepix3, a time-stamping readout chip with 256×256 pixels of 55x55 μm^2. The processing electronics in each pixel records the time of arrival of hits which cross a preset threshold and stores it as a timecode in a memory inside the pixel. The light sensitive sensor has a thin entrance window with excellent quantum efficiency and anti-reflective coating, see a photograph of the sensor on a chip card and examples of single photon hits in the figure above. A salient feature of Timepix3 is the data driven readout with only 0.5 μs dead time, which allows multi-hit functionality at the pixel level and enables the readout rate of 80Mpix/sec.

II. Photon Counting With Tpx3Cam

We explore here the idea of counting photons coming from a fiber by their time stamping with a position sensitive sensor. If the photons are separated enough not to overlap in the sensor they can be reconstructed as standalone hits and counted as independent events even if they arrived at the same time.



The Tpx3Cam camera has excellent parameters to enable this technique. In our study we used the Hong-Ou-Mandel (HOM) effect to characterize the performance of the photon counting. The principle of the HOM effect is based on the fact that identical photons arriving at a beam splitter will be bunched and will exit the splitter on the same side without producing a coincidence between two different fibers due to the two-photon interference which cancels photon amplitudes to exit on two different sides of the splitter. If the photons are distinguishable, for example if they arrive at the beam splitter not at the same time or, in general, are in orthogonal modes, they could exit on the opposite sides and produce a coincidence between the two fibers. Thus, the HOM effect allows to produce well defined states with single and double photons propagating in a fiber. We used this property to characterize the proposed above counting technique as shown in the above figure for coincidence rates in two single fibers and between the two fibers. The horizontal axis is the delay between two photons entering the beam splitter expressed in mm. The HOM dip and bunched photon peaks are clearly visible.

[1] A. Nomerotski, Imaging and time stamping of photons with nanosecond resolution in Timepix based optical cameras, Nuclear Instruments and Methods in Physics Research A937, 26 (2019).

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