SPAD arrays for asynchronous Quantum Ghost Imaging:

Achieving real-time video processing and imaging with diffuse reflection

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Asynchronous Quantum Ghost Imaging (aQGI) is a novel imaging technique allowing both imaging and ranging with entangled photons. It is based on time-tagging the detections of individual photons of a pair and subsequent identification of correlated ones by coincidence detection. Since the identification is made in post-processing the optical setup necessary for traditional (heralded) QGI can be highly simplified and imaging can be achieved without prior knowledge of the scene.
The 3D imaging capability has been demonstrated recently both in a Time-of-Flight scheme [1], achieving cm resolution, and a two-plane imaging method [2], allowing resolution on the order of µm. Moreover, the capability of performing image acquisition near video-rate has recently been demonstrated [3], however the coincidence processing was still limited to post-processing after the measurement.
Here we'll demonstrate a new camera scheme, based on the camera chip in [3], which is extended by an additional TCSPC input on the FPGA board of the camera. This input allows time-tagging of the idler detector by the camera itself, allowing direct referencing of detections. It also simplifies the detection side of the setup, so only the idler detector, camera and a processing unit are needed for coincidence processing. The camera has been improved further by optimizing detector readout, increasing its duty cycle to ~90%.
With this camera we were able to achieve imaging and real-time processing with frame rates up to 88 fps with the major limitation being the coupling and detection rate of the idler detector (see Fig.1). We were further able to achieve imaging with a diffuse reflective target, demonstrating the first QGI images with diffuse reflection ever taken in the IR.

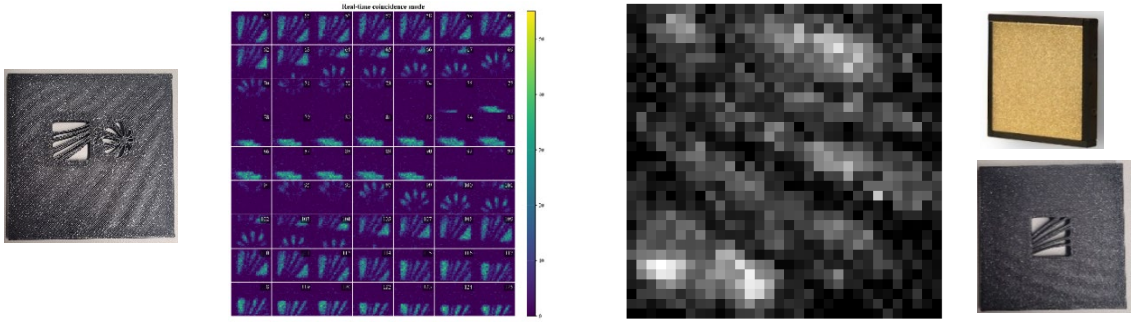

Fig. 1: *left: Still images of a moving mask imaged in transmission and processed at 26 fps, right: Image of diffuse reflection taken at 0.5m distance with the diffuse target used (Infragold)*

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References

[1] C. Pitsch, D. Walter, et al. "3D quantum ghost imaging," Appl. Opt. 62, 6275-6281 (2023)

[2] A. Eshun, D. Davenport, et al. "3D quantum ghost imaging microscope," Optica 12, 1109-1112 (2025)

[3] C. Pitsch, A. Suprano, et al. "Toward video-rate quantum ghost imaging," *APL Photonics* 1 October 2025