System development of a real-time quantum distillation imager

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Project Type: *Master Thesis* *Section:* *Microengineering*
Official Start Date: *Anytime*
Submission of Final Report: *TBD*
Presentations at Group Meeting: *TBD*

Spontaneous Parametric Down Conversion (SPDC) crystals are used to generate entangled photons and can be used to image scenes where classical light illuminations have limitations. By correlating the single-photons detected at the signal and at the idler, the measurement's SNR can be greatly increased. Among applications that uses this concept are quantum LIDAR, correlation plenoptic imaging and Hong-Ou-Mandel imaging.

At AQUA lab, state-of-art Single Photon Avalanche Diode (SPAD) sensors are developed. SwissSPAD2 is one of such sensors, a gated binary-frame imager. This chip has a resolution of 512x512 and a frame rate of up to 97kHz. Having a gated architecture makes it ideal to be used together with a picosecond pulsed laser. For quantum distillation imaging, two such sensors are synchronized, yielding better resolution and allowing flexible optical setups.

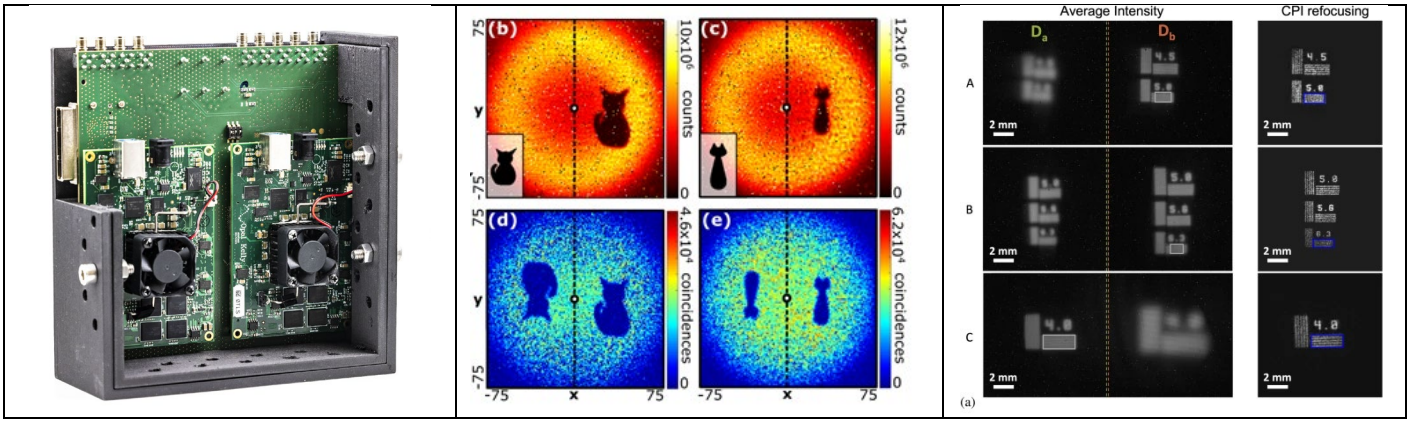

Figure 1. *Left Camera module [1]. Center: Quantum Distillation imaging. [2] Right: Correlation plenoptic imaging [3].*

The student will learn about quantum distillation concept and correlations methods. The student will do the PCB design to merge the PCIe of the two cameras together and the corresponding RTL design on a Xilinx FPGA that is integrated in a commercial board, XEM8360 by Opal Kelly. Furthermore, the student will implement the RTL design for correlation, either by coding in VHDL, Verilog, or through Vivado's high level synthesis tool. Additionally, the merged signal from the two cameras is planned to be sent to a GPU over PCIe 3.0.

[1] Paul Mos et al, SwissSPAD2/3: a family of natively digital, time gated SPAD cameras with continuous streaming at up to 100 kpfs and picosecond system-level synchronization for quantum imaging applications, Proceedings Volume 12912, Quantum Sensing, Imaging, and Precision Metrology II; 129120Q (2024) https://doi.org/10.1117/12.2692931
[1] Defienne, H., Zhao, J., Charbon, E. & Faccio, D. Full-field quantum imaging with a single-photon avalanche diode camera. Phys. Rev. A 103, 042608 (2021).
[3] Massaro, G., Mos, P., Vasiukov, S. et al. Correlated-photon imaging at 10 volumetric images per second. Sci Rep 13, 12813 (2023). https://doi.org/10.1038/s41598-023-39416-8