Compact Single Photon Sensor

Silicon Photomultiplier-Based Photon Detection with Integrated FPGA Processing

Graduate

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Introduction: Applications of laser microscopes in fields like biomedical engineering and biology require precise optoelectronic systems, such as fluorescence lifetime imaging microscopy (FLIM), where time-stamped single-photon detection enables imaging. The goal of this thesis is to miniaturize an existing system, which was originally created by the institute for microelectronics, embedded systems, and sensors (IMES) in collaboration with the University of Zurich. This prototype consists of a photon sensor and separate signal processing electronics. The development focus on integrating all components of the FLIM system into a compact, unified system that can deliver processed measurement data to a user interface on a PC.

Approach / Technology: To enable compact and efficient photon detection, a silicon photomultiplier (SiPM) with integrated cooling is utilized. While SiPMs present challenges in signal amplification due to their inherently low signal-to-noise ratio (SNR), they offer significant advantages in terms of size and cost compared to other sensor technologies. A custom sensor PCB with a low-noise optimized analog signal chain was developed to achieve short and steep electrical pulses when a photon is detected. Further evaluation and processing of the digitized pulse signal is performed on a field programmable gate array (FPGA) module, integrated on a custom miniaturized baseboard. The system is integrated into a specially designed compact housing as visible in figure 3. The software enables FPGA to PC communication via ethernet and displays real-time plots, as in figure 2.

Conclusion: The developed single-photon sensor is more compact than existing solutions and capable of processing and transmitting the data directly. Moreover, the new hardware is approximately four times more cost-effective than the current prototype system in use and at least an order of magnitude cheaper than any commercially avaiable system. The outcome of this bachelor thesis has the potential to advance research in single-photon detection and make a significant contribution to the field of FLIM.

Figure 1: Setup for direct photon-pulse measurements
Own presentment

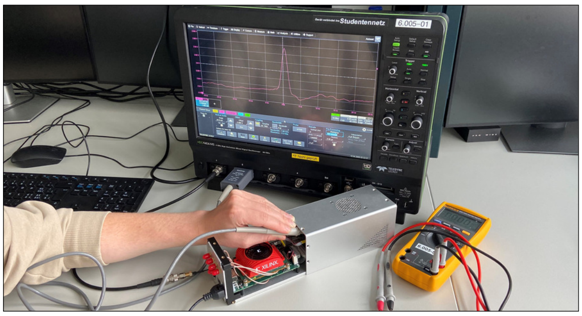


Figure 2: Quantitative detected photons at different light intensities
Own presentment

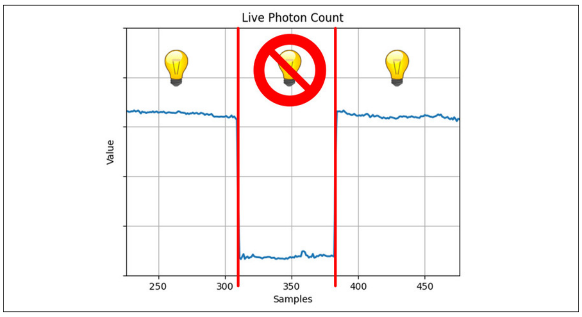
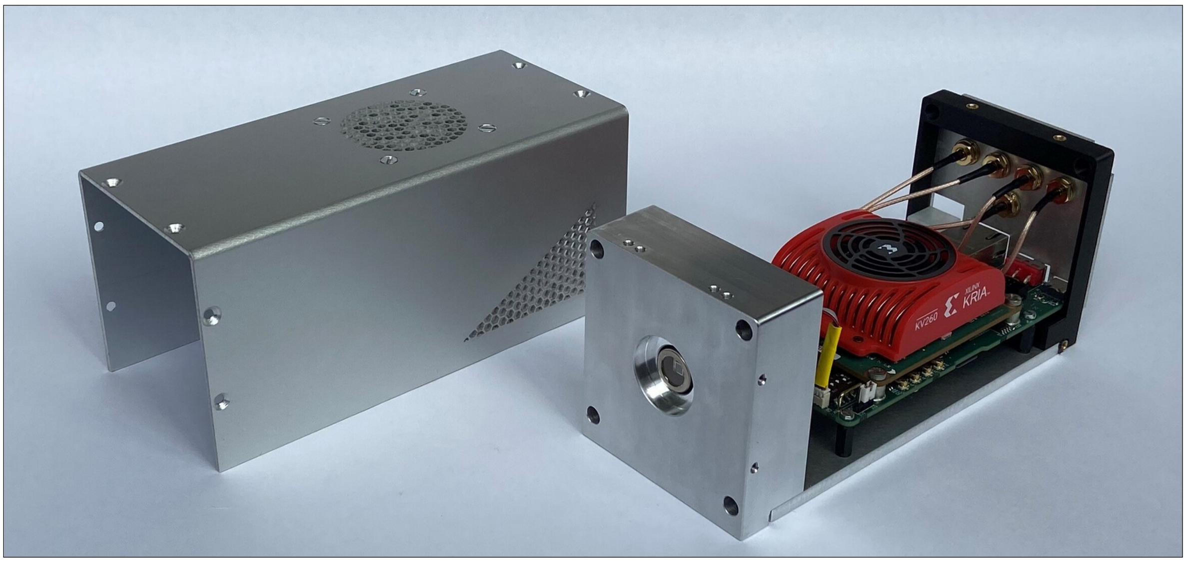


Figure 3: Photon detection system installed in the compact housing
Own presentment



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