Characterization of a TCSPC SPAD camera and measurement of diffusive mediums

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Single Photon Avalanche Diode (SPAD) cameras are widely used in LIDAR-based applications. However, for in tissue reconstruction applications the world is experimenting. In robotic-assisted surgery, surgeon would benefit from a spatial map of the surgical environment. The challenge is that in tissue, the light is scattered, absorbed which hardens the localization of specific objects, which requires development of complex algorithms.

At AQUA lab state-of-art sensors SPAD sensors are developed. One such sensor is Piccolo, a Time Correlated Single Photon Counting (TCSPC) SPAD sensor with 32 x 32 pixels and a Time to Digital Converter (TDC) resolution of 50ps. These sensors have a very promising future in close-in LIDAR applications as they form the histogram of the detected light. Fully characterization of phantom silicon with similar properties as human body and wavelength in visible domain is the next step forward as it will help developing systems where the user has control over the mapped area and real time feedback. A newer version of Piccolo implements a gated architecture which allows masking the photons that are reflected by the surface, therefore improving further the in-depth measurements.

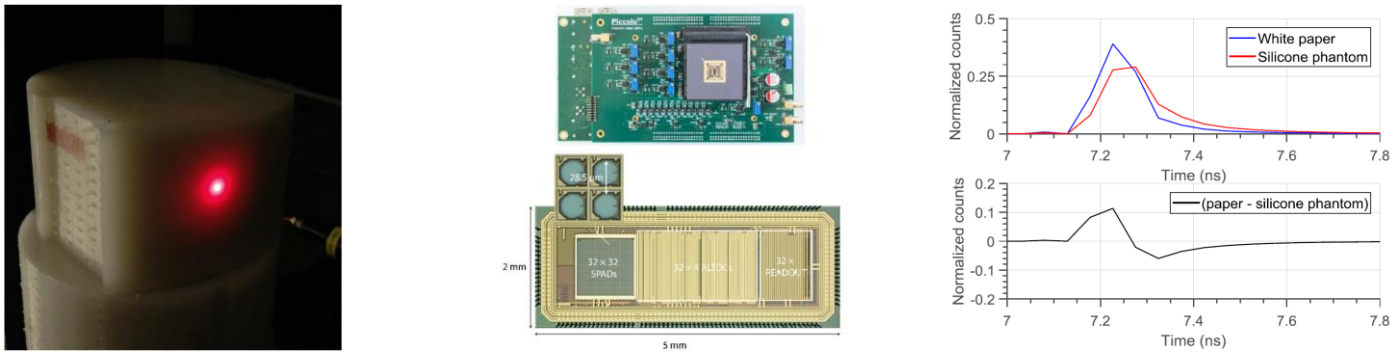

Figure 1. *Left : Light diffusing in silicon phantom [1]. Center: Piccolo, 32x32 TCSPC CMOS SPAD image sensor, PCB (top) micrograph with pixel inset (bottom) Right: Comparison of timing histogram between white paper and silicone phantom in same position, histograms (top) and difference (bottom)*

The student will update an existing Printed Circuit Board (PCB) design to accustom the gated architecture of Piccolo sensor, update an existing FPGA design to enable the use of gated architecture, characterize the gate performance and the Time-to-Digital Converters (TDCs) performance and experiment with a picosecond laser in various wavelengths and measure diffusive phantom silicon material with the gated architecture camera. The student will apply existing algorithms on obtained data to reconstruct the objects hidden beneath the phantom.

Through this project, the student will be familiarized with PCB layout design, FPGA firmware design, laser operation and safety, light behavior in diffusive environments, and reconstruction algorithms for TCSPC systems.

[1] S. Lindner,A Close-in LIDAR for Diffusize Media based on a 32 x 32 CMOS SPAD Image Sensor, IISW 2019.