Compressive Sensing with a 100×100 Digital SiPM for FLIM

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Conventional wide-field Fluorescence Lifetime Imaging Microscopy (FLIM) systems are limited by the trade-off between framerate and spatial resolution. Highly integrated Single-Photon Avalanche Diodes (SPAD) arrays capable of measuring lifetimes on-chip are pushing forward these limits but the bottleneck of data transmission constrains the scaling of the number of pixels.
Compressive Sensing (CS) promises to relax this constraint. The theory of CS proves that a sparse signal can be recovered even after sampling it below the Shannon-Nyquist limit [1]. As natural images are sparse, they can be reconstructed from a number of measurements that is a fraction of the number of pixels. This leads to potentially faster framerates, lower power consumption and a more efficient use of hardware resources. Image sensors optimized for CS has been proposed in the past but only few works are concerned with SPAD-based sensors [2].
In this work, CS is performed using a 100×100 CMOS digital Silicon Photon-Multiplier (dSiPM) that generates a single value corresponding to the total number of photons impinging on its SPADs within 4 tuneable gating windows. An arbitrary subset of pixels can be masked using a programmable SRAM memory allowing to perform CS measurements with a Bernoulli sensing matrix in hardware, as depicted in Fig. 1. Our experiments demonstrate that images can be recovered by the Fast Iterative Shrinkage-Thresholding Algorithm (FISTA) with a good quality of reconstruction for different Compression Ratios (CR) and integration times, as shown in Fig. 2.
This work paves the way for the design of innovative SPAD sensors optimized for CS targeting FLIM, Light Detection and Ranging (LiDAR) and high-speed imaging.

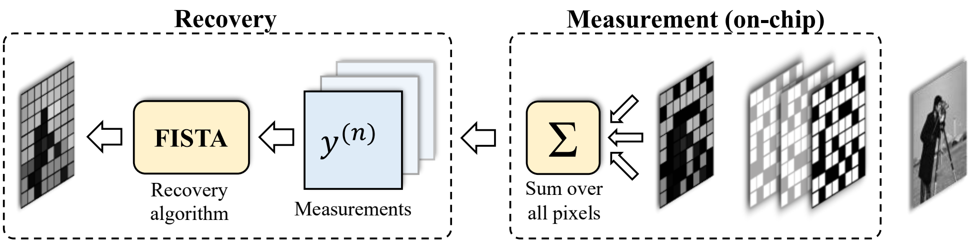

Fig. 1: *Overview of compressive sensing for imaging.*

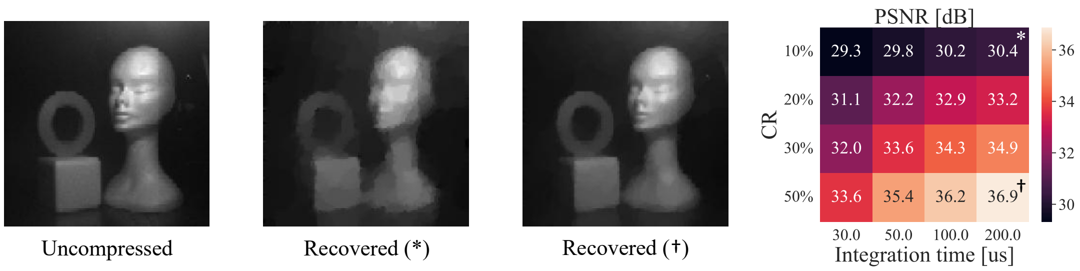

Fig. 2: *Comparison of an uncompressed image and its reconstruction via CS. The quality of reconstruction is quantified by the Peak Signal-to-Noise Ratio (PSNR)*

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References

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