A 96x96 Pixel SPAD Sensor for Flash LiDAR in SWIR

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Single-photon LiDAR sensors have been widely adopted due to their picosecond-level timing resolution and high sensitivity, which allows for the use of lower laser power. Single-photon avalanche diode (SPAD) arrays are increasingly utilized in direct time-of-flight systems, benefiting from CMOS scaling and high computational power. Operating in the short-wave infrared (SWIR) spectrum is highly desirable as it reduces scattering, lowers solar background, and increases the permissible laser power under eye-safety limits. Because silicon is insensitive beyond 1000 nm, the InGaAs/InP material system is commonly used for this spectral range [1].

In this work, we present flash LiDAR results using the room-temperature 96×96 InGaAs SPAD camera previously introduced in [2, 3]. The sensor operates in a time-gated regime, which provides the advantage of significantly reducing background counts while controlling afterpulsing. This operational mode also enables gated flash LiDAR, offering a much simpler and more scalable architecture compared to traditional time-to-digital converter (TDC) histogramming approaches.

Figure 1 presents indoor gated flash LiDAR measurements acquired using the full 96×96 array, featuring devices with a 10 µm active diameter operating at a 2 V excess bias. Binary frames at 50 kHz were used with 1 gate per frame. A reference image captured with a commercial camera is shown in Fig. 1(a). 2D intensity image in Fig. 1(b) was illuminated by a halogen lamp and recorded without optical filtering by accumulating 1,000 binary frames, plotted in grayscale. Fig. 1(c) shows the depth image obtained by uniform illumination of the scene through a diffuser by a 1030 nm pulsed laser (NKT Photonics Origami LP; <200 fs pulse width, 120 mW average optical power, 100 MHz repetition rate). A 3 ns gate was incrementally shifted in 30 steps of 250 ps. By accumulating 1,000 binary frames per step, a total acquisition time of 600 ms was achieved demonstrating the robust performance of InGaAs SPAD arrays for scalable SWIR flash LiDAR.

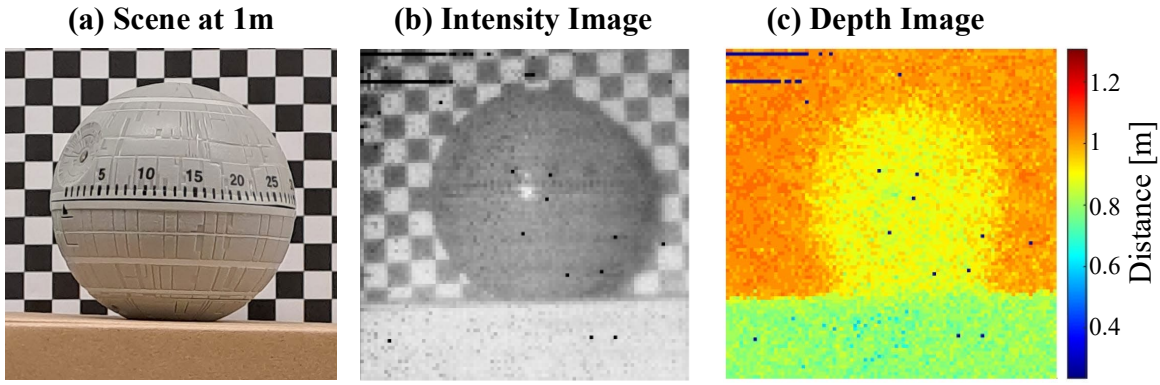

Fig. 1: *Indoor flash LiDAR measurements. (a) Target scene at 1 m. (b) Intensity image with infrared lamp illumination. (c) Flash LiDAR depth image at 1030 nm.*

References

[1] M.A. Itzler et al., Journal of Modern Optics, 54(2–3), pp. 283–304, (2007).

[2] H.K. Yildirim et al., Opt. Express 34, 5064-5078 (2026).

[3] P. Rustige et al., Proc. SPIE 13192, 131920V (2024)