Multispectral 3D Depth and Polarisation Enhanced Imaging via Metasurface-Integrated SPAD Array

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This work presents a compact LiDAR imaging system capable of depth, colour, and polarisation-enhanced imaging at the single-photon level. The system integrates a time-gated CMOS (Complementary Metal-Oxide-Semiconductor) SPAD (Single-Photon Avalanche Diode) detector array [1, 2] that enables rapid, parallel, time-tagged acquisition of photon events across the entire sensor via TCSPC (time-correlated single-photon counting). This array is combined with a metasurface-based plasmonic filter stack [3], allowing RGB, polarisation as well as 3D imaging enabled by single photon time of flight measurement.

Benchmark experiments on complex scenes demonstrate depth retrieval using as few as three detected photons per pixel with acquisition times as short as 1 ms, highlighting the suitability of the platform for low-light or resource-constrained environments. The inclusion of polarisation-resolved channels can further enhance target material discrimination, to enable more robust identification of low-reflectivity and specular surfaces. This capability allows the system to distinguish man-made objects from natural clutter, such as differentiating engineered components from surrounding foliage—even under challenging imaging conditions.

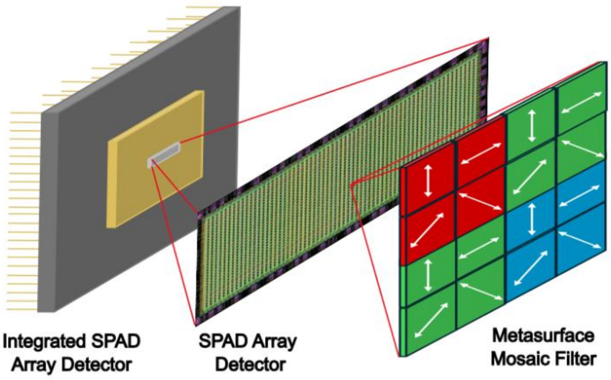

Fig. 1: Filter integrated array and a close-up of the layout of an individual macro-pixel, showing the 4 by 4 array.

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References

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