High-Resolution Lidar with Material-Discriminating Capabilities using Waveguide-Integrated SNSPDs

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Superconducting nanowire single-photon detectors (SNSPDs) offer outstanding performance in photon counting, with state-of-the-art benchmarks in detection efficiency, dark count rate, and timing accuracy, making them well-suited for remote sensing. Waveguide-integrated SNSPDs provide greater design flexibility compared to conventional fiber-coupled SNSPDs, allowing for optimization of nanowire geometry and integration into customized photonics circuits. We demonstrate the potential of waveguide-integrated SNSPDs in light detection and ranging (Lidar) applications, achieving low jitter values with short nanowire geometries that enable sub-millimeter ranging resolution in multi-shot measurements. By combining time-of-flight, jitter, and count rate information, we generate 3D visualizations of remote objects using Delaunay triangulation [1], as illustrated in Fig. 1 (left). In single-shot operation, we approach millimeter resolution by leveraging multi-photon absorption in the nanowire [2], reducing jitter values to approximately 10 ps.
The high timing accuracy of our Lidar system also allows us to resolve the temporal signatures of photons reflected off remote targets, revealing material-dependent variations in latency time distribution, as shown in Fig. 1 (right). By analyzing the temporal point-spread functions, we can distinguish between turbid and non-turbid materials, such as metals versus thermoplastic polymers and ceramics. Furthermore, our analysis of the required dwell time for distinguishing scattering materials indicates that a few milliseconds are sufficient for differentiating ceramics from metals. Our results demonstrate that customized waveguide-integrated SNSPDs in highly integrated Lidar systems can provide novel remote sensing capabilities, enabling applications such as digital twin generation, autonomous navigation, and environmental monitoring.

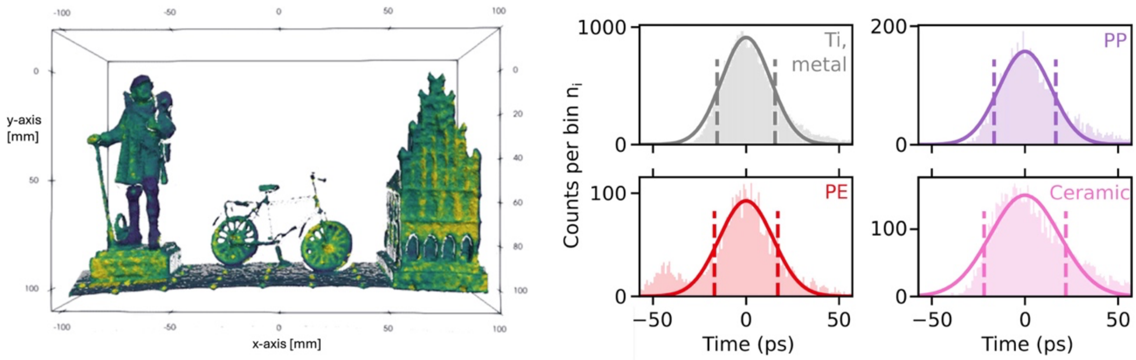

Fig. 1: *Left: 3D visualization of remote objects, combining distance information with peak height and jitter data. Right: Gaussian analysis of four test targets (titanium (Ti), Polypropylene (PP), Polyethylene (PE) and Macor (ceramic), showing different numbers of photons received from the target and the FWHM of their latency time distribution.*

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References

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