Scalable FPGA-based Time Tagging Electronics For Photon Counting

Noureldin Amer[1*], Robert Hadfield[1]

[1]*James Watt School of Engineering, University of Glasgow, University Ave., Glasgow G12 8QQ, Scotland, UK*

Modern single-photon measurement systems require timing hardware that can deliver picosecond resolution, low cost, and a practical path to multi-channel scaling. While commercial time-tagging instruments offer excellent performance, their cost, size, and limited flexibility can restrict use in experimental platforms requiring custom integration or scalable detector readout. This is especially relevant for applications such as quantum key distribution (QKD), Light Detection and Ranging (LiDAR), and fluorescence lifetime measurements.

In this work, we present a compact field-programmable gate array (FPGA)-based time-to-digital converter (TDC) for picosecond-scale photon timing, implemented on a Xilinx Artix-7 28 nm platform for time-correlated single-photon counting and related fast timing applications. The system uses a high-speed comparator front-end together with an FPGA-based tapped delay line architecture to convert detector events into precise digital timestamps. Fine timing information is extracted from the sampled state of the tapped delay line and used to determine the time difference between synchronization and photon-event channels.

Hardware validation confirmed stable delay-line operation and consistent fine-bin encoding across the timing path. The system was experimentally evaluated using superconducting nanowire single-photon detector (SNSPD) signals in a TCSPC-style measurement, achieving an effective timing resolution of 15 ps. The platform is configured for 8 channels, with calibrated testing completed for 4 channels so far, and ongoing work toward full 8-channel operation and future extension to 16 channels and beyond. Raw timing data can be accessed for external processing and system integration.