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SOPHIA: Photon Counting and Time-to-Digital Conversion using Single Photon Avalanche Diodes

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SOPHIA (Solo PHoton Imaging Array) is a Single Photon Avalanche Diode (SPAD) array with built-in Time-to-Digital Converter (TDC) and photon counting logic, designed at the Rutherford Appleton Laboratory (RAL; Oxford, UK).

SOPHIA was designed to demonstrate the technologies needed for use in applications requiring high sensitivity or precise timing resolution. It achieves this through the use of SPAD pixels with active feedback circuitry for quenching the diode. Present on the device are three main SPAD arrays: pixels with hit counting logic (HITFLAG), pixels with time to digital conversion logic (TDC), and pixels without logic for SPAD measurements. These are arranged into four 16 x 16 arrays of 100 μm pixels, each with a 5 μm radius SPAD. Each area can be operated independently to allow for individual testing.

The HITFLAG variant contains logic to record whether the SPAD was triggered during an experimental window, and the TDC variant expands on this by adding a gated ring oscillator and ripple counter to record the time that the SPAD triggered. Using the gated ring oscillator as a 4-bit fine counter, and the ripple counter as the 4-bit course counter, it was possible to achieve time resolution of sub-1 ns with a total experimental window of 255 ns.

Here we will focus on the arrays with in-pixel logic, and present details of the design of this sensor and data showing the operation of the HITFLAG and TDC pixel variants.

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