Progress on chip-based spontaneous four-wave mixing quantum light sources

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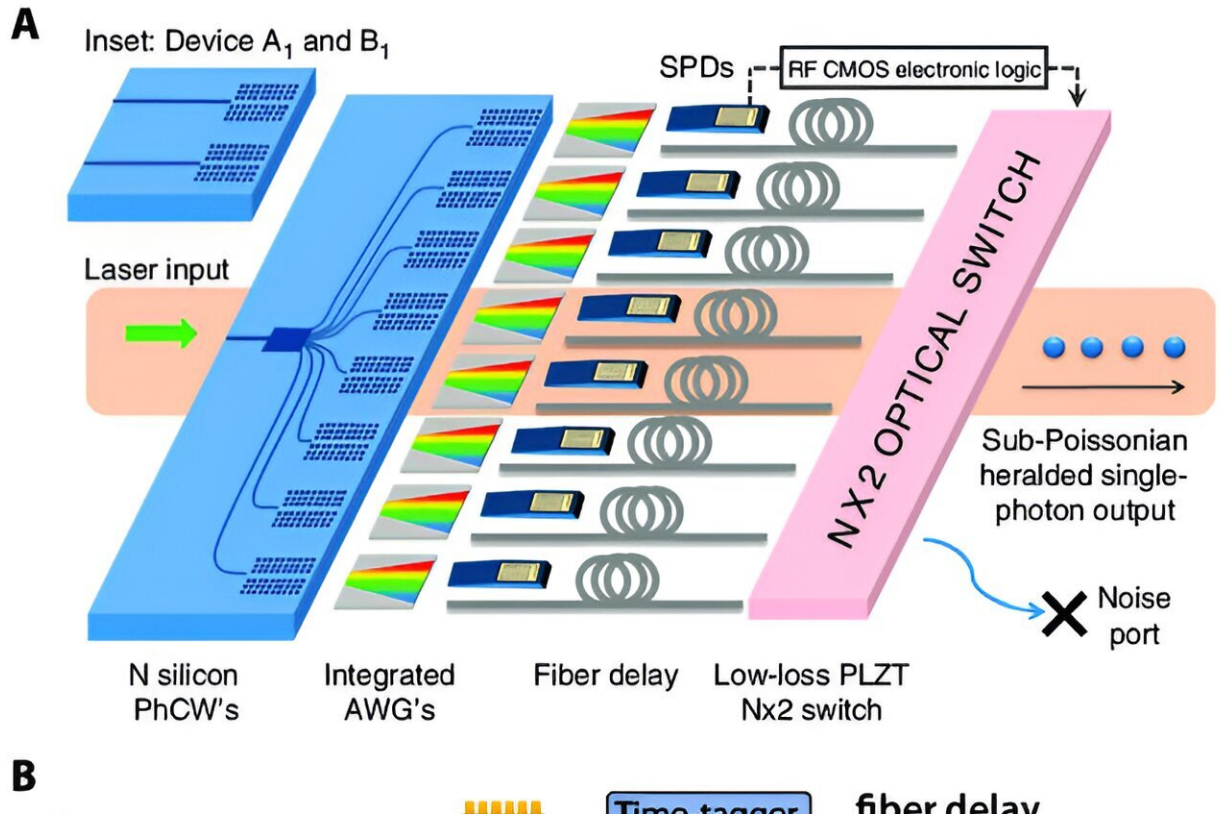

Experimental setup for heralded photon using (A) spatial multiplexing technique [18] and (B) temporal multiplexing technique [20]. Credits: Benjamin J. Eggleton (A) and Yunhong Ding (B). *Advanced Devices & Instrumentation* (2023). DOI: 10.34133/adi.0032

A single-photon detector (SPD) is sensitive to incidence of individual

quanta of light and has many applications in photonics, such as fluorescence measurements, laser ranging, optical time-domain reflectometer, and quantum optics experiments.

Near-infrared SPDs at the telecommunication wavelength of 1550 nm are indispensable for fiber-optic QKD, with choices including cryogenic superconducting nanowire single-photon detectors (SNSPD) and electrically-cooled InGaAs avalanche photodiodes (APDs). Between them, APDs have practical advantages for compactness, low cost, and not requiring ultra-low temperature refrigeration.

Under Geiger mode, APD's strong capacitive response to sub-nanosecond gating must be rejected through purpose-designed readout circuit so as to enable detection of weak photon-induced avalanches. Rapid gating and readout circuits add challenges to modularization and miniaturization, which is a necessary step to serve a wide range of applications.

A research group has recently developed a novel readout circuit that incorporates a surface acoustic wave (SAW) filter into an asymmetric radio-frequency Mach-Zehnder interferometer, referred to as ultra-narrowband interference circuit (UNIC), and realized exceptional performance for narrow-band rejection of the SPD capacitive response. The work is published in the journal *Advanced Devices & Instrumentation*.

Thanks to the long group delay of the SAW filter, the UNIC interferometer can produce an ultra-narrrow band rejection with a manufacturing tolerance easily achievable in the RF track lengths.

The UNIC can provide a wide and continuous pass band in the frequency domain and therefore brings little distortion into the avalanche signal. The team reports their development of a standalone InGaAs SPD

module that fully integrates driving and readout electronics as well as temperature regulation and compensation.

Its dimension is measured just 8.8×6×2 cm^3 and is nearly a factor of 4 smaller in volume than the most compact existing detector module that uses a monolithically integrated readout circuit. Simultaneously, this size reduction does not bring performance deterioration.

The research team uses their previous UNIC techniques for the APD signal readout, but adds an automatic temperature compensation to ensure an optimal performance over a wide ambient temperature range.

With a 1.25 GHz clock input, the module is characterized to have comparable performance to its counterpart built with benchtop equipment. The UNIC-SPD exhibits excellent performance with a net detection efficiency of 30% at an afterpulsing probability of 2.4 % under 3 ns hold-off time. The compact size and state-of-the-art performance allow the UNIC-SPD module a huge potential for single-photon imaging and high-speed quantum key distribution.

More information: Haoyang Wang et al, Progress on Chip-Based Spontaneous Four-Wave Mixing Quantum Light Sources, *Advanced Devices & Instrumentation* (2023). DOI: 10.34133/adi.0032

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