Spectral Measurement of Breakdown Flashes in InGaAs Avalanche Photodiodes

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Avalanche photodiodes (APDs) operating in Geiger mode are commonly used for detecting single photons in quantum key distribution (QKD) schemes. It was reported previously that the silicon APDs emit light during the avalanche breakdown process after detecting of a photon [1].

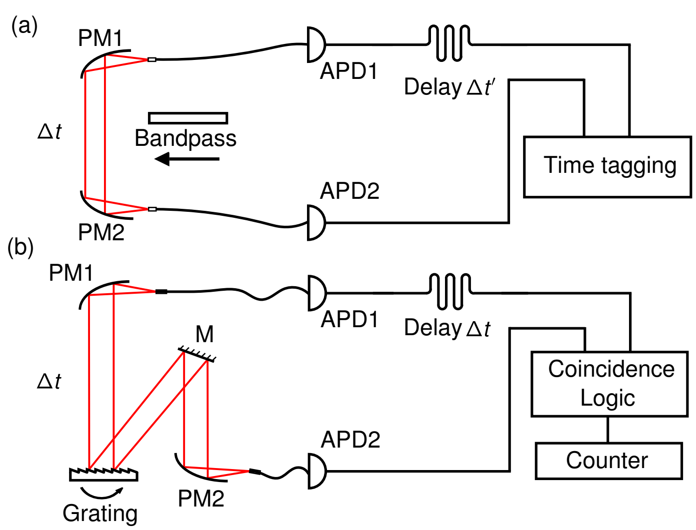

Figure 1: (a) Experimental setup for detecting the breakdown flash from two InGaAs APDs. (b) Experimental setup for measuring the spectral distribution of the breakdown flash.

This breakdown fluorescence is also observed in Indium Gallium Arsenide (InGaAs) APDs [2], which are core components in QKD systems at telecom wavelengths (1260 $\sim$ 1625nm). This fluorescence light (referred to as "breakdown flash") gives rise to potential eavesdropping attacks to the QKD system, as an eavesdropper may gain timing- or other information of the detected photons by observing the breakdown flash leaked back to the optical channel.

In this work, we characterise the breakdown flash from two commercial InGaAs single photon counting modules (ID220 from ID Quantique). We measure their spectral distribution, and demonstrate that the breakdown flash can be greatly suppressed by applying spectral filtering to the optical channel.

As shown in Fig. 1(a), two InGaAs APDs are optically coupled through free space with a pair of parabolic mirrors (PM1 and PM2). The arrival times of the electrical signals from the two APDs are timestamped and the histogram is shown in Fig. 2(a). One peak corresponds to events where APD1 fires and emits a breakdown flash, which is then detected by APD2, the second one to a pair event in reverse direction. The timing separation between the two peaks corresponds to twice the propagation time Δt of the flash photons between the APDs. When an optical bandpass filter ($1550 \pm 6\,\mathrm{nm}$) was inserted between PM1 and PM2, the number of breakdown flash events could be suppressed by a factor of over 100 [see Fig. 2(b)].

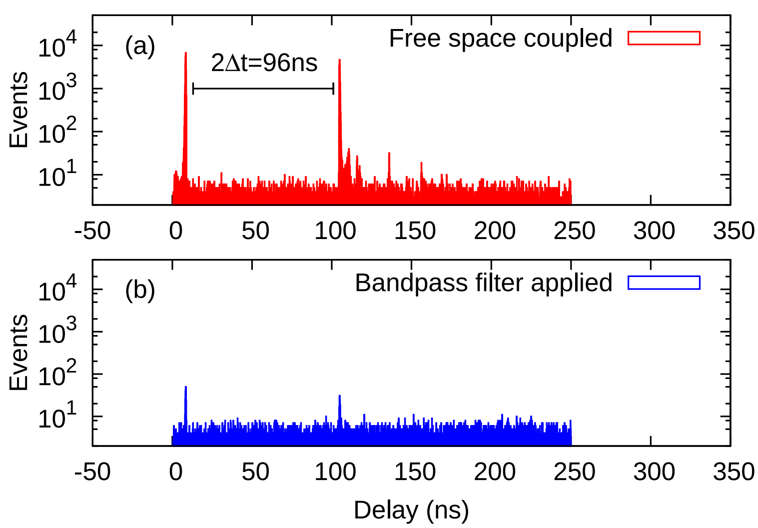

Figure 2: Histogram of the signal arrival times from the two APDs, recorded by a timestamping unit.

To measure the spectral distribution of the light from the breakdown flash, a grating spectrometer as shown in Fig. 1(b) was employed. The APDs, connectorized to multimode optical fibers, are coupled through a pair of parabolic mirrors (PM1 and PM2) via a blazed reflection grating. An electrical delay is applied to APD1(2) to match the optical delay Δt between them. The grating is oriented at different angles to record coincidence events at different wavelengths.

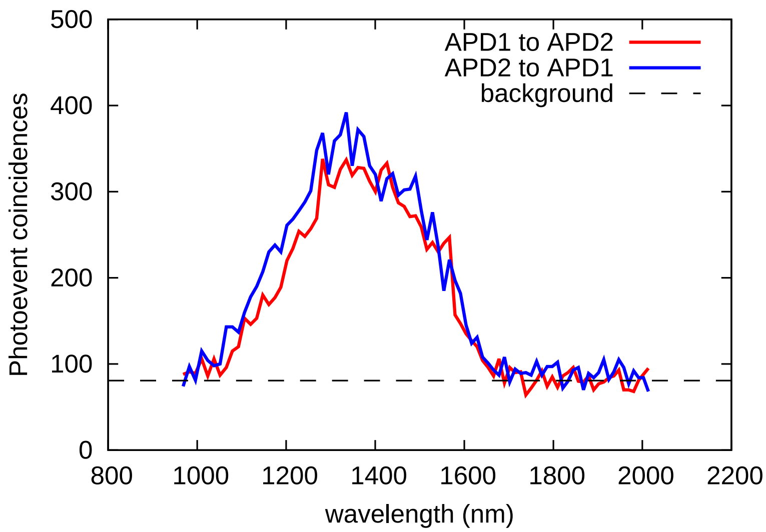

Figure 3: Spectral distribution of breakdown flash. The spectra ranges from 1000 nm to 1600 nm and peaks at about 1300 nm.

Figure 3 shows the spectral distribution of the breakdown flash. The spectra ranges from 1000 nm to 1600 nm. This result is uncorrected for the transmission efficiency of the grating and the detection efficiencies of the two APDs.

References

[1] Christian Kurtsiefer, Patrick Zarda, Sonja Mayer, and Harald Weinfurter. The breakdown flash of silicon avalanche photodiodes-back door for eavesdropper attacks? *Journal of Modern Optics*, 48(13):2039–2047, Nov 2001.

[2] Loris Marini, Robin Camphausen, Chunle Xiong, Benjamin Eggleton, and Stefano Palomba. Breakdown flash at telecom wavelengths in direct bandgap single-photon avalanche photodiodes. *Photonics and Fiber Technology 2016 (ACOFT, BGPP, NP)*, 2016.