Measurement and modeling of the nonlinearity of avalanche single photon detectors and photovoltaic photodiodes

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There is a huge variety of photodetectors in the optical domain that all measure the radiation power incident on their input aperture or active area. Several parameters characterize those photodetectors: wavelength range, accuracy, detection bandwidth, dynamic range, noise, resolution, and nonlinearity. Of all these parameters linearity is usually considered last, and often it is specified only very crude by the manufacturers. Although quite a few publications have studied the linearity of such systems in the past [1-3], our approach [4] is a modern implementation of the so-called superposition method targeted specifically at the high requirements of quantum optics. Our method additionally allows us to extract the transfer function of the detector.

The advantage of the superposition method is the fact that it does not rely on a radiation standard and that the measurement principle is very simple. Our setup (Fig. 1(a)) consists of two light sources S1 and S2 – in our case two highly intensity stable lasers. Polarization filters P on rotation stages allow us to vary the intensity of the beams. After the beams are overlapped on a beam splitter BS they are directed onto the detector. Shutters S in each of the beams give the possibility to measure the intensity of each of the beam individually (I1 and I2) as well as the intensity of both beams combined (I1+2).

With this setup we investigated different types of detectors, among those a Perkin Elmer SPCM-AQRH-12-FC single photon counting module (SPCM) operating in Geiger-mode, and a Physimetron A139-001 transimpedance photoreceiver (based on a Hamamatsu S2386-18K silicon photodiode) operating in photovoltaic mode. In the case of the SPCM the nonlinearity can be described by the dead time model and we can extract the dead time with high accuracy. Fig. 1 (b) shows the residual signal function r= I1+2-(I1+I2) for our SPCM which gives the deviation from a perfectly linear detector.

Compared to previous work, we improved the setup by complete automatization in order to take much more samples and implemented a new data processing scheme. This scheme allows different levels of analysis: As previously demonstrated [3], the series expansion of the detection system transfer function can be recovered by least-squares approach. Moreover, we also found a fast and intuitive linearity characterization based on the net balance of the signal. Furthermore, modern nonlinear optimization techniques are readily available, which allow us to actually fit the transfer function.

References