APN-003

Image sensor noise

Overview

When preforming measurements with linear array sensors, there are different noise sources:

- Sensor readout noise
- Amplifier noise (introduced by amplifiers between the sensor and the ADC)
- Digitizing noise (ADC noise)
- Shot noise (Poisson noise)
- Dark noise

Sensor readout noise

The analog output of a sensor has an intrinsic readout noise which is specified irrespectively of the integration time. This is generated by the readout electronics of the sensor and is specified by N_{read} [mVrms] and a dynamic range DR1 (V_{sat}/N_{read}). For example, the Hamamatsu S11639-02 has a readout noise of N_{read} = 0.4 mVrms and a saturated maximum output signal of V_{sat} = 2.0 V. This gives a maximum signal-to-noise ratio (SNR) of DR1 = 2.0 V / 0.4 Vrms = 5000 (74 dB)

Amplifier noise

The output of the sensor is passed through a buffer amplifier and a differential amplifier which provides the input to the ADC (analog-to-digital converter). The LineScan cameras use low-noise amplifiers with noise levels less than 0.1 Vrms and a signal-to-noise ratio (SNR) of 86 dB. Amplifier noise can be ignored.

Digitizing noise

The ADC (analog-to-digital converter) adds additional noise:

- Offset
- Linearity
- Analog noise

The LineScan uses high-performance ADCs with a signal-to-noise ratio (SNR) of 84 dB. Digitizer noise can also be ignored.

Shot noise

Shot noise is often neglected but can be the largest noise source. Shot noise is related to the effective well-depth of each pixel in a sensor. Well-depth is the number of electrons that can be accumulated in a pixel before it saturates. The shot noise signal-to-noise ratio (SNR) is given by sqrt(N), where N is the well-depth. For example:

- S11639 (high-sensitivity, active pixel sensor): well-depth = 80 ke^-, shot-noise SNR = 49 dB
- S12198 (high-gain): well-depth = 5892 ke^-, shot-noise SNR = 67 dB

For applications where the light intensity is high enough to get a strong signal a sensor with a larger well-depth will provide the best noise performance. For weak light signals (e.g. fluorescence measurements) a high-sensitivity sensor is the better option.

Dark noise

For short integration times (exposure times) dark noise can be ignored. Dark noise only plays a role for integration times above 1 ms. CMOS sensors usually have better dark noise performance and can handle longer integration times. InGaAs sensors have worse dark noise performance and for integration times above 10 ms a cooled InGaAs sensor is recommended.

Summary

- Sensor readout noise can contribute to measurement performance, but has medium impact.
- Amplifier and ADC noise in the LineScan was minimized for best performance.
- Shot noise depends on the application. High-sensitivity sensors are recommended for fluorescence and other low-light measurements and sensors with a large well-depth are recommended for transient absorption experiments.
- Dark noise for fast spectroscopy can be ignored where integrations times are short. CMOS sensors can be used for integration times up to 100 ms. However, for InGaAs snesors with integration times above 10 ms a cooled InGaAs sensor is recommended to reduce dark current/noise.