On the cutting edge of semiconductor sensors: towards intelligent X-ray detectors

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Response linearity

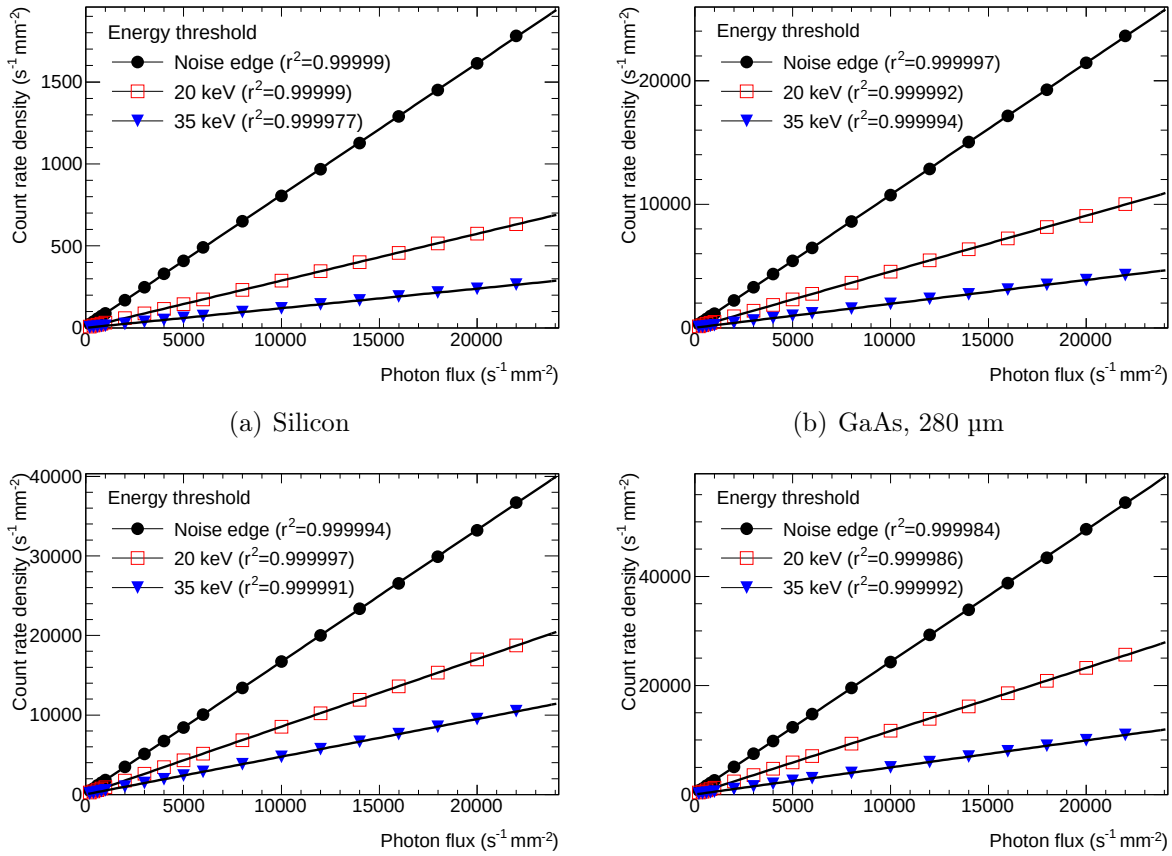
As discussed in Section 1.2.3, a spectral decomposition of both signal and noise is only possible when a system can be considered linear and shift invariant. Therefore, the linearity of each detector studied in Chapter 6 is measured for a wide range of photon fluxes.

The photon flux at the detector's input stage is estimated using the X-ray spectrum simulation programme SpekCalc [117]. This software calculates the output spectrum of a tungsten-target X-ray tube at one meter distance. In accordance to the set-up as described in Section 6.3.2 on page 122, Figure 6.6 on page 122 shows the simulated spectrum for a peak tube voltage of 70 kVp, a beam angle of 19.5 °, a 21 mm thick aluminium filter and 650 mm of air. SpekCalc calculates a Bremsstrahlung output of approximately 2.8 µGy/mAs at 1 meter. From this it is estimated that the photon flux at the detector's surface is:

$$\frac{2.8}{0.65^2} \cdot 0.1 \cdot 30.17 \cdot 10^3 \approx 2 \cdot 10^4 \text{photons/mm}^2\text{s}\,,$$

where 0.65^2 accounts for the intensity at 65 cm following the inverse-square law, 0.1 is the tube's operation current of 100 µA and $30.17{\cdot}10^3$ is a conversion factor from air kerma[1] to quanta per area, which is defined by the IEC standard.
Figure D.1 shows recorded count-rate density as a function of incoming photon flux for each of the detectors at three different levels of the threshold DAC. All four detectors are operated at a bias voltage that corresponds to a lateral diffusion with a standard deviation of 10 µm (see Table 6.2 on page 126). The plots show excellent linearity (coefficients of determination near 1) and hence the detectors allow for a spectral decomposition of both signal and noise when shift-invariance is assumed.
The yields derived from the slope of the line fits are listed in Table D.1.

[1] Kerma stands for Kinetic Energy Released per MAss. Air kerma parameterises the absorbed dose in air.



(a) Silicon

(b) GaAs, 280 µm

(c) GaAs, 450 µm

(d) CdTe

Figure D.1: Linearity
The recorded count-rate density as a function of incoming photon flux for each of the detectors at three different levels of the threshold DAC. The photon flux is estimated using the simulated Bremsstrahlung output dose at one meter distance from the tube's focal spot.

Table D.1: Detector yield

Sensor	**Yield**		
	Noise edge	*20 keV*	*35 keV*
Si, 300 µm	0.080	0.029	0.012
GaAs, 280 µm	1.1	0.45	0.19
GaAs, 450 µm	1.7	0.85	0.47
CdTe, 1000 µm	2.4	1.2	0.50