Table 2.1.6
Important detector properties at 8 keV as reported by various vendors

Only typical values are given to allow approximate comparisons. Detector properties strongly depend on individual detector designs and are subject to high development rates.

		Gas ionization (Xe/CO_2 gas filling)		
	Scintillation	Wire based (0D)	Wire based (1D/2D)	Micro-gap (1D/2D)
DQE	∼95%	∼95%	∼80%	∼80%
Dynamic range	>6 × 10^6	>10^6	>10^4 (1D) >10^6 (2D)	>8 × 10^7 (1D) >10^9 (2D)
Maximum global count rate	>2 × 10^6 c.p.s.	>7.5 × 10^5	>10^5 (1D) >4 × 10^4 c.p.s. (2D)	>8 × 10^5 (1D) >1.6 × 10^6 c.p.s. (2D)
Maximum local count rate	n/a	n/a	>10^4 (1D) >10^4 c.p.s. mm^{-2} (2D)	>9 × 10^5 c.p.s. mm^{-2} (1D, 2D)
Noise	∼0.3 c.p.s.	∼1 c.p.s.	∼1 c.p.s. (1D) <5 × 10^{-4} c.p.s. mm^{-2} (2D)	<0.01 c.p.s. (1D) <5 × 10^{-4} c.p.s. mm^{-2} (2D)
Energy resolution	∼3500 eV (∼45%)	∼1600 eV (∼20%)	∼1600 eV (∼20%)	∼1600 eV (∼20%)
Detection mode	Photon counting	Photon counting	Photon counting	Photon counting

	Semiconductor				
	Si(Li)	Strip	Pixel	CCD	CMOS
DQE	>98%	>98%	>98%	∼20–60%	∼75%
Dynamic range	>10^6	>7 × 10^6 per strip	>10^9	>5 × 10^4	>1.6 × 10^4
Maximum global count rate	>10^5 c.p.s.	>10^8 c.p.s	>10^7 c.p.s. mm^{-2}	n/a	n/a
Maximum local count rate	n/a	>7 × 10^5 c.p.s. per strip	>10^4 per pixel	n/a	n/a
Noise	∼0.1 c.p.s.	∼0.1 c.p.s. per strip	∼2.5 × 10^{-3} c.p.s. mm^{-2}	<0.1 c.p.s. per pixel	<0.05 c.p.s. per pixel
Energy resolution	∼200 eV (∼4%)	∼1600 eV (∼20%)†	>1000 eV (∼12.5%)	n/a‡	n/a
Detection mode	Photon counting	Photon counting	Photon counting	Integrating§	Integrating

† ∼380 eV/∼5%; Wiacek *et al.* (2015). ‡ >300 eV/>6% in photon-counting mode, see text. § Photon-counting mode possible, see text.

as the detector of choice. An important disadvantage these days is the limitation to 0D detection.

2.1.7.2.2. *Gas-ionization detectors*

The gas-ionization detectors in current use are proportional counters and can be of the 0D, 1D or 2D detection type. Common to all proportional counters is a gas-filled chamber permeated by a non-uniform electric field between positive and negative electrodes, held at a constant potential difference relative to each other. Typically the noble gases Ar or Xe are used as gas fill, mixed with a small amount of quenching gas such as CH_4 or CO_2 to limit discharges. When an X-ray photon travels through the gas-filled volume, it may be absorbed by a noble-gas atom, resulting in the ejection of an electron (photoelectric and Compton recoil). This electron, accelerated by the electric field towards the anode, will cause an avalanche by subsequent ionization along its path (gas amplification), generating an electric pulse which can be registered. The height of the generated pulse is proportional to the energy of the incoming X-ray photon and permits the use of pulse-height selection to achieve moderate energy resolution.

2.1.7.2.2.1. Wire-based proportional counters

In a point proportional detector (0D detection), the pulses generated are measured at one end of a wire (or a knife edge). Position-sensitive (1D and 2D detection) proportional detectors have the added capability of detecting the location of an X-ray photon absorption event. In a 1D proportional detector, pulses are detected at both ends of the wire. Thus the time difference between the measurements of a given pulse can be used to determine the location of the discharge. 2D proportional counters consist of three arrays of wires (multiwire proportional counter, MWPC; Sauli, 1977; Charpak *et al.*, 1968), where one array forming the anode plane is placed between two cathode arrays with their wires oriented parallel and orthogonal to the anode-plane wires, respectively.

Low count rates and low-to-moderate detector noise result in low-to-moderate dynamic ranges. Wire-based proportional counters are not competitive with micro-gap and semiconductor detectors, as can be seen in Table 2.1.6, and are therefore being driven out of the market.

2.1.7.2.2.2. Micro-gap detectors

The maximum count rates in 'classical' metal-wire-based proportional counters are severely limited by the long ion-drift times in the chamber (which typically have a cathode to anode spacing of ∼10 mm). This issue has been successfully addressed by so-called micro-gap technology using parallel-plate avalanche chambers with a readout electrode separated from a resistive anode. The key feature is the resistive anode, which allows a very small amplification gap (1–2 mm cathode to anode spacing) at an increased average electric field intensity, while preventing discharges (Durst *et al.*, 2003; Khazins *et al.*, 2004). As a result, micro-gap detectors can achieve count rates several orders of magnitude higher than classical proportional counters at higher position sensitivity. Micro-gap detectors of the 1D and 2D detection type are available. Moderate count rates and very small

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