processing circuits. The counting losses are affected by the time modulation, if any, of the source, as, for example, with storage rings (Arndt, 1978).

Counting losses can affect the behaviour of detectors in two different ways. In most analogue detectors and in counters with parallel read-out, each pixel behaves as an independent detector and the counting loss at any point depends only on the *local* counting rate. In other devices, such as multiwire proportional chambers with delay-line read-out (see Subsection 7.1.6.2), the whole detector becomes dead after an event anywhere in the detector and what matters is the *global* counting rate.

Fortunately, the fractional counting loss is the same for all parts of the pattern so that the *relative* intensities in a stationary pattern are not affected.

7.1.6.1.3. *Dynamic range*

The lowest practically measurable intensity is determined by the inherent background or noise of the detector. Some form of discrimination against noise pulses is usually possible with a detector that counts individual photons, but not, of course, with integrating detectors.

The maximum intensity at which a *counter* can operate is determined by the dead-time. In the case of an *integrating or analogue detector* with a variable gain, there is a trade-off between maximum intensity and DQE. Such a device can often be regarded as having an output signal with an amplitude $S = NV/M$ that is a noise-free representation of N, the number of photons detected in the integrating period of the device, where V, the maximum signal amplitude, is produced by M photons in this period. M can be varied by altering the gain of the detector. The noise can be regarded as a fixed fraction $1/r$ of the maximum amplitude V that is added to the signal. Then the DQE will be

$$\begin{aligned}\varepsilon &= S^2/\sigma^2 N\\ &= (1 + M^2/r^2N)^{-1}.\end{aligned} \qquad (7.1.6.2)$$

This equation shows the importance of having as small a value of $1/r$ as possible; it also demonstrates that, for a given value of r, M can be increased only at the expense of a reduced DQE. This is valid for X-ray film (Arndt, Gilmore & Wonacott, 1977), for television detectors (Arndt, 1984), for the integrating gas detectors discussed in Subsection 7.1.6.2, and for many semiconductor X-ray detectors.

7.1.6.1.4. *Spatial resolution*

The spatial resolution of a PSD is determined by the number and size of resolution or picture elements (pixels) along the length or parallel to the edge of the detector. In most diffraction experiments, the size of the pattern can be scaled by altering the distance of the detector from the sample and what is important is the angular resolution of the detector when placed at a distance where it can 'see' the entire pattern. We shall see below that linear PSD's can be made with up to 2000 pixels and that area detectors are mostly limited to fewer than 512 × 512 pixels. The sizes of pixels range from about 10 μm for semiconductor PSD's to about 1 mm for most gas-filled detectors.

The *useful* number of pixels of a detector is determined by its point-spread function (PSF). This is the relative response as a function of distance from the centre of a point image on the detector. PSF's are not necessarily radially symmetrical and may have to be specified in at least two directions at right angles, for example along and perpendicular to the lines of a television raster scan. The width of the PSF at the 50% level determines the amount of detail visible in a directly viewed image. The accuracy of intensity measurements may depend more critically upon the width of the PSF at a lower level, since a weak spot may be immeasurable when sitting on the 'tail' of a very intense one. For various physical reasons, the PSF's of *all* PSD's, including X-ray film, have appreciable tails.

The spatial resolution of a detector is affected by parallax: when an X-ray beam is absorbed in a thick planar detector at an angle φ to the normal, the width of the resultant image is smeared out exponentially and its centroid is shifted by an amount $\sin\varphi/\mu$. For 8 keV X-rays incident at 45° on a xenon-filled counter, for example, this shift is about 4 mm for a filling pressure of 1 atm and 0.4 mm for a filling pressure of 10 atm. These figures illustrate the desirability of high-pressure xenon (Fig. 7.1.6.2) for gas-ionization detectors intended for wide-angle diffraction patterns.

7.1.6.1.5. *Uniformity of response*

All PSD's show long-range and pixel-to-pixel variations of response to larger or smaller extents. These can be corrected, in general by means of a look-up table, during data processing, but the measurements necessary for the calibration are often time-consuming. The output signals of many analogue detectors contain fixed-pattern noise that is synchronous with the read-out clock. This noise is usually removed during data processing, which in any case requires the subtraction of the background pattern.

7.1.6.1.6. *Spatial distortion*

In most detectors, there is some spatial distortion of the image. Again, the necessary calibration procedure may be time-consuming. Distortions cause point-to-point variations in pixel size, which produce response variations additional to those from other causes.

Corrections for spatial distortion and for non-uniformity of response have been discussed by Thomas (1989, 1990) and by Stanton, Phillips, Li & Kalata (1992*b*).

7.1.6.1.7. *Energy discrimination*

The amplitude of the signal due to a single photon is usually a function of the photon energy. The variance in this amplitude, or the full width at half-maximum (FWHM) of the pulse-height spectrum, for a monoenergetic input, depends on the statistics of the detection process. A sharp pulse-height-distribution (PHD) curve may permit simultaneous multi-wavelength measurements with a suitable counter, or at least afford a reduction of the background by pulse-height discrimination. In an analogue

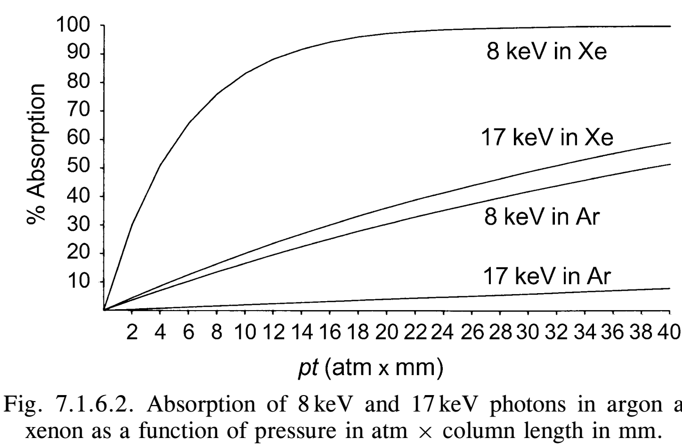

Fig. 7.1.6.2. Absorption of 8 keV and 17 keV photons in argon and xenon as a function of pressure in atm × column length in mm.

 references