10.3.2.6 Spatially resolving detectors

Detectors for the measurement of the spatial distribution of radiation i.e. *spatially resolving detectors*, can be divided into two groups:

(i) the photosensitive area consists of a matrix of discrete photosensitive elements, the *pixels* (picture elements), forming an *array* with the facility to read out the information simultaneously or sequentially.

(ii) the photosensitive area consists of a single photosensitive element that must be scanned (e.g., *image dissection tube*).

A further distinction can be made between one and two-dimensional detectors that are *instantaneous* (nonstoring) or *time integrating* (storing). In addition, time integration can be intrinsic to the detector or can be performed by associated electronics. The *array geometry* is defined by the total photosensitive area of the detector, the dimensions of the pixels, and their *centre-to-centre spacing*, which mainly determines the *spatial resolution*. In the case of linear arrays its geometry is also determined by the height of the sensing area. *Dummy arrays*, as blanked-off portions of arrays, can be used to compensate for dark current. Readout from arrays can be either *sequential* or *random access* in multiplexed operation.

An arrangement of a number of photodiodes on a single chip is a *photodiode array*. *Interchannel crosstalk* due to scattering of radiation or leakage of electric charges influences the detectivity of the respective element and the spatial resolution. A *pyro-electric photodetector array* consists of a monolithic array of pyro-electric detector elements arranged in one or two dimensions.

An image dissection tube is a two-dimensional radiation detector in which the electron image produced by a photo-emitting surface, usually a photocathode, is focused in the plane of a *defining aperture*. Magnetic or electric fields scan this image across the defining aperture (See Note 1). In *position-sensitive photomultiplier tubes* spatial resolution is obtained with the help of a partitioned photocathode. *Position-sensitive proportional counters* for spatially resolved detection of X-rays make use of both single-wire and multi-wire arrangements.

A large group of microchannels assembled in a block is called a *microchannel plate* (MCP). The MCP can be used as a position-sensitive detector with each channel acting as an independent electron multiplier. Gain limitations by ion-feedback can be overcome by juxtaposing two suitably cut and oriented MCPs to include a sharp bend at the junction (the *chevron orientation*) or by using curved channels. The electron cloud leaving the channels can either be detected directly or, indirectly, by light conversion using a fluorescent screen.

Note 1 Normally, photoelectrons passing the defining aperture enter an electron multiplier chain for amplification and detection.

X-ray imaging can be performed with an *Anger camera* in which a large diameter scintillator is coupled to an array of photomultiplier tubes by *fibre optics*. X-ray imaging may also be achieved in *multi-crystal cameras* where many small crystals individually scintillate.

Time-integrating photodiode arrays are photodiode arrays with storage facilities by virtue of integrating capacitors in the associated electronics. A *vidicon* is a vacuum tube containing a photosensitive area, or *target*, and an *electron gun* to read the signal from the target. The *silicon target* consists of a two-dimensional array of Si-photodiodes having a common cathode and isolated anodes. Irradiation of the target causes the production of electron-hole pairs which, by recombination, leads to a depletion of the surface charge. When the beam scans a depleted area, a *recharging current* flows. The time interval before the next measurement can be made, caused by the inability to completely recharge the depleted area by a single scan, is called the *lag*. In a *silicon-intensified-target vidicon* (*SIT vidicon*) a curved photocathode is irradiated through a *fibre optic face plate*. The silicon target of a vidicon is then used to detect the accelerated and focused photoelectrons originating at the photocathode.

A *charge-transfer device* has a *metal oxide semiconductor* (MOS) structure that is composed of many independent pixels where charge is stored in such a way that the *charge pattern* corresponds to the irradiation pattern. These devices can be linear or two-dimensional. According to the method used to detect the charge pattern, two types of charge-transfer devices can be distinguished: *charge-coupled devices* (*CCDs*) and *charge-injection devices* (*CIDs*). In a charge-coupled device the signal charge is transferred to the edge of the array for readout. Alternatively, multiplexing can be used. The charge packets are transferred in discrete time increments by the controlled movement of *potential wells*. In a *linear CCD* the charge is moved in a stepwise fashion from element to element and is detected at the end of the line. A *two-dimensional array CCD* consists of a two-dimensional assembly of interconnected linear CCDs. Because the charge from wells located far from the output must undergo many hundreds of transfers, the *charge transfer efficiency*, CTE, is of concern. The on-chip summing of charges in adjacent pixels along rows or columns is called *binning*. The *full-frame array* has a single photosensitive array for photon collection, charge integration and charge transport. It is read out a line at a time and incident radiation must be blocked during the readout process. A *frame-transfer array* is composed of two arrays in series, the image and storage arrays. The storage array is covered with an opaque mask. After the image array is irradiated, the entire exposed electronic image is rapidly shifted to the storage array for readout. While the masked storage array is read out, the image array may acquire charge for the next image. Direct X-ray and broad wavelength-band imaging and detection can be performed by a *thinned CCD* irradiated from the side opposite the electrodes.

In a charge-injection device (CID) the accumulated charge is not transferred serially out of the array, but is shifted between two adjacent capacitors. In *nondestructive readout* the output is derived from the electric potentials on these two capacitors, which retain the information. Alternatively, the output can be derived from the stored charge after it has been injected into the substrate, thus destroying the original information.

An *intensified array* consists of an intensifier directly coupled to a diode or charge transfer array. The intensifier is composed of a semitransparent photocathode and a magnetically or electrostatically focused accelerating region. A *Digicon* is such a detector adapted to X-ray spectroscopy.