International Tables for Crystallography (2006). Vol. F, Section 7.1.4, p. 147.

indirectly coupled to the sensor, such as a Vidicon or CCD. Many of the designs employ image intensifiers to raise the signal strength of the visible image above the noise of the sensor system. Some designs employ cameras operated at video rates, with frames accumulated in the attached computer or on videotape. Other designs use cooled cameras operated in a slow-scan mode, which greatly reduces noise. The X-ray exposure is integrated in the camera, then read out once at the end of the integration period.

Most of these systems would be classified as complex, but several of them are working reliably today in laboratories with conventional X-ray sources. The image intensifiers improve the DQE of the systems, while sacrificing dynamic range and image sharpness. In addition, intensifiers are sensitive to magnetic fields, requiring great care in their use if proper detector calibration is to be maintained.

Considerable enhancement to the television-type detector is made possible by the low-noise imaging capabilities of CCDs, described in Chapter 7.2. In this case, high DQE can be maintained without intensification when the CCD is cooled and read with slow-scan electronics. As such, these detectors are much more robust and have improved imaging qualities.

7.1.4. Future detectors

Commercially available X-ray detectors have evolved from X-ray film and point diffractometry to area gas-proportional counters, to image plates, and now to CCD detectors. Two new X-ray detector technologies are on the horizon. One is based on the large-area amorphous semiconductors and thin-film transistor arrays which are being intensively developed by many large companies for medical radiography (reviewed by Moy, 1999). The radiographic need is to be able to cover very large areas (*e.g.* 0.5 m^2) with a high-spatial-resolution detector that is sensitive to hard X-rays. A number of these detectors are at the moment (1999) poised for introduction, but they are specialized for radiographic applications and are poorly suited for relatively long, low-noise integration of low-energy X-rays. It remains to be seen whether the technology will succeed and whether it can be modified for quantitative crystallographic applications.

A second technology being developed specifically for quantitative X-ray diffraction is based on solid-state pixel array detectors (PADs) (Iles *et al.*, 1996; Datte *et al.*, 1999; Barna *et al.*, 1997; Rossi *et al.*, 1999). In a PAD, X-rays are stopped directly in a semiconductor and the resulting signal is processed by electronics integrated into each pixel. Direct conversion of X-rays into electrical signals in a high-grade semiconductor has many advantages: many signal electrons are produced for each X-ray, and the conversion medium is very linear, has low noise and is well understood. Since each pixel has its own electronics, there is enormous flexibility in performing local signal processing. In principle, PADs have tremendous advantages of sensitivity, flexibility, noise and stability. The challenge will be to make PADs of a size and format useful for crystallography, while still being sufficiently affordable to be commercially viable.

references