International Tables for Crystallography (2006). Vol. C, Section 7.2.4.1, p. 642.

1986), which relies on the phenomenon of photostimulated luminescence. Here the active area is a coating of a photostimulable phosphor that can store energy when excited by electrons. The energy absorbed is then emitted as photons when the medium is illuminated with visible or infrared radiation and this signal is detected using a photomultiplier. The read signal is provided by a scanning He–Ne laser so that, as with the detectors in Subsections 7.2.3.3 and 7.2.3.4, information is recorded in parallel but accessed serially. Initial experiments suggest that the imaging plate offers higher sensitivity and a wider dynamic range than most film, but currently suffers from inferior spatial resolution. Recent discussion of the performance and limitations of imaging plates has been supplied by Mori, Oikawa, Katoh, Miyahara & Harada (1988) and Isoda, Saitoh, Moriguchi & Kobayashi (1991).

7.2.4. Serial detectors

7.2.4.1. *Faraday cage*

The Faraday cage is the most convenient means of determining electron-beam currents. It consists of a small electrically isolated cage with a small hole in it through which electrons enter. Provided the hole subtends a sufficiently small solid angle and the inner surface of the cage is made of a material with a low back-scattering coefficient, the probability that any electrons will re-emerge is negligible. An electrometer is normally used to measure the charge that has entered the cage.

The main use of the Faraday cage is to calibrate other detectors when absolute electron intensities are required. It also serves a very important role when the total specimen exposure in an experiment must be kept below a critical value owing to the susceptibility of the specimen to radiation damage. As electron charge is being measured, the Faraday cage may be used with electrons of any energy.

7.2.4.2. *Scintillation detectors*

One of the most widely used total flux detectors is a scintillator, the output from which is coupled into a photomultiplier by a light-pipe. In the first stage, an incident electron deposits its energy in the scintillator, producing a number of light photons with an energy deficiency of up to $\sim 20\%$ (Herrmann, 1984). By careful design of the light-pipe, an appreciable fraction of the photons will reach the photomultiplier, which should have a photocathode whose quantum yield peaks around the wavelength of the photons from the scintillator. Even though the quantum yield of the photocathode is likely to be < 0.2, the number of photoelectrons emerging from the photocathode for each electron incident on the scintillator should be considerably greater than unity, provided the incident electron energy exceeds ~ 10 keV. With lower-energy electrons, it is advantageous to provide an additional acceleration onto the scintillator to ensure that an adequate number of photons is generated.

Following the production of photoelectrons, considerable multiplication takes place down the dynode chain of the photomultiplier and a current pulse may easily be detected at the anode. Electron counting is therefore a possibility and to take advantage of this over as wide a current range as possible scintillators with very fast decay times (10^{-8} to 10^{-7} s) should be used. Such scintillators have the additional advantage that they may be used in systems where beam scanning is performed at TV rates.

When the rate of arrival of electrons at the detector appreciably exceeds $10^6\,\text{s}^{-1}$, it becomes increasingly difficult to distinguish the output from individual electrons and the detector must be operated in an analogue mode. Despite this, the individual electron pulse-height distributions from good scintillators are sufficiently narrow that values of DQE greater than 0.8 may be obtained (Chapman & Morrison, 1984). Scintillators meeting both speed and pulse-height distribution requirements include plastics (*e.g.* Nuclear Enterprise NE102A) and Ce-doped YAG (Schauer & Autrata, 1979). It should be noted that the materials discussed in Subsection 7.2.3.1 are generally unsuitable for fast detector systems because of their relatively long time constants and the existence of an afterglow that persists for several seconds.

To handle the large dynamic range encountered in diffraction patterns, it is advantageous to use a detector system capable of both counting the arrival of individual electrons and making analogue current measurements. Such a system, which allows signals whose magnitudes differ by a factor of 10^8 to be recorded with a high DQE in a single scan, has been described by Craven & Buggy (1984). More general advantages of detector systems based on scintillation counters are their desirable input/output characteristics, which are essentially linear, and the fact that a quantitative measure of electron intensity is directly available in a form suitable for input to a computer. Analysis of the data may thus begin as soon as its collection is completed.

The susceptibility to radiation damage of many high-efficiency scintillators, resulting in a diminution of light output with increasing use, is probably the major disadvantage of these detectors. Of importance in some instances is the fact that the entire detection system is relatively bulky and it may not always be possible to position it satisfactorily within the apparatus.

7.2.4.3. *Semiconductor detectors*

The most commonly used semiconductor detector is a silicon photodiode whose p–n junction is reverse biased. A fast electron incident directly on the device produces electron–hole (e–h) pairs and the two charge carriers are swept in opposite directions under the influence of the bias field. Thus, a charge pulse is produced and as, on average, an e–h pair is produced for every 3.6 eV deposited in the silicon, a 100 keV incident electron produces a pulse equivalent to $\sim 3 \times 10^4$ electrons. In practice, many devices have a contact layer on the silicon surface (which itself may be less perfect than the bulk of the material) so that some of the energy of the incident electron is lost before the sensitive volume is reached. As the energy deposited in surface layers is rarely less than 5 keV, semiconductor detectors are unsuitable for direct use with low-energy electrons.

The magnitude of the signal produced by each incident electron in a semiconductor detector is typically $\sim 10^4$ times lower than that emerging from the anode of the photomultiplier in scintillation detector systems and it is difficult to measure such small signals without adding substantial noise. A further complicating factor arises from thermally generated carriers, which can give rise to a substantial dark current from detectors of area $> 1\,\text{mm}^2$. Thus, photodiode detectors cannot normally be operated in an electron-counting mode and suffer from a low DQE whenever incident electron currents are small. To optimize their performance in this range, the device should be cooled (to reduce the thermally generated signal) and the electron beam should be scanned relatively slowly so that high-gain low-noise amplifiers may be used for subsequent amplification of the signal from the photodiode. Above the low-signal threshold, the output from the photodiode varies linearly with incident electron intensity and is once again in a form suitable for direct display or for being digitized and stored.

references