International Tables for Crystallography (2006). Vol. C, Figure 7.1.7.2, p. 634.

In order to recognize the defect image in the perfect region, the signal-to-noise ratio (SNR) R_I of the image must be

$$R_I \equiv (S_d - S_p)/\sigma_p = \delta C(q\nu_p t)^{1/2} \geq \kappa, \qquad (7.1.7.3)$$

where S_d = signal height of the defect image, C = contrast of the defect image, $C = (S_d - S_p)/S_p$; and κ = threshold SNR of 1–5 (Rose, 1948).

Sensitivity is expressed by the intensity required for a certain signal height to the noise height of the imaging system and is proportional to the value of $q\eta_1 \ldots \eta_s$. As is seen from (7.1.7.3), however, the ratio of the signal to the photon noise depends only on the absorption efficiency q. For example, a 100 µm thick silicon-diode array (Rozgonyi, Haszlo & Statile, 1970) and 15 µm thick lead oxide camera tubes (Chikawa, 1974) have similar sensitivities for Mo $K\alpha$ radiation, but $q = 0.15$ and $q = 0.6$, respectively; the former obtains the sensitivity with a higher conversion efficiency $(\eta_1\eta_2 \ldots \eta_s)$ of absorbed photon energy and gives a $(0.15/0.6)^{1/2} = 0.5$ times lower SNR.

It is clear from the foregoing discussion that imaging systems should be evaluated by three factors: resolution, integration time for observation, and SNR.

7.1.7.2. *Imaging system*

There are two kinds of imaging system (*e.g.* Green, 1977); one is a direct method in which X-ray input images are converted directly into video signals and the other is an indirect method in which X-ray images are first converted into visible-light images to be observed by the usual electro-optical system. In the latter, phosphor screens are widely used and the visible images can be magnified by a lens. However, the resolution is limited by the thickness of the phosphor screen that is required for a satisfactory absorption efficiency. In contrast, the direct method provides a high resolution.

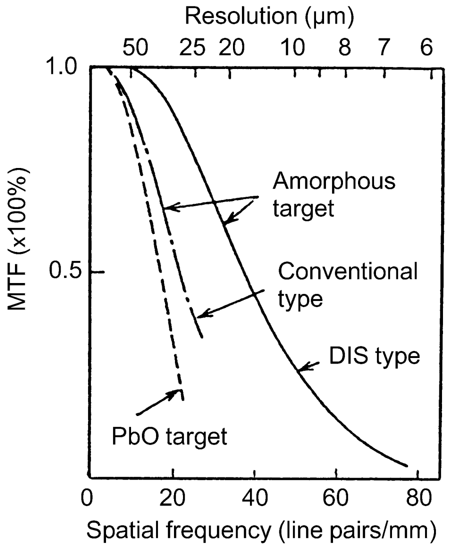

Fig. 7.1.7.2. Square-wave modulation transfer function (MTF) measured for the DIS-type, conventional-type Se–As and PbO camera tubes. This function shows the magnitude of brightness modulation in the output image obtained for an input image with a square-wave intensity distribution and is defined by

$$\mathrm{MTF} = \left(\frac{I_{o\max} - I_{o\min}}{I_{o\max} + I_{o\min}}\right)\left(\frac{I_{i\max} - I_{i\min}}{I_{i\max} + I_{i\min}}\right)^{-1},$$

where $I_{i\max}$ and $I_{i\min}$ are the maximum and minimum intensities of the input image, respectively, and $I_{o\max}$ and $I_{o\min}$ are those of the output. DIS stands for diode-operation impregnated-cathode Saticon.

Various types of indirect method are discussed in Subsections 2.7.5.2 and 7.1.6.5. Here only the direct method will be described in some detail.

A direct method using X-ray TV camera tubes has been used for real-time topography (Chikawa & Matsui, 1994). The construction and operation of an X-ray TV camera tube are similar to those of the conventional video pick-up tube, except for a beryllium window, as shown schematically in Fig. 7.1.7.1. The popular one is a vacuum glass tube which is 15 cm long and 25 mm in diameter. An X-ray sensing photoconductive layer such as Se (McMaster, Photen & Mitchell, 1967), or PbO (Chikawa, 1974) is placed on the inner surface of the window at one end of the tube and is scanned by a narrow electron beam from a cathode on the opposite end to convert image charges on the photoconductive layer into video signals. Therefore, the resolution depends upon the characteristics of the photoconductive layer and the electron-beam size on the layer.

The camera tube with a PbO photoconductive layer has absorption efficiencies of $q = 0.6$ for Mo $K\alpha$ and 0.8 for Cu $K\alpha$, using a PbO layer with a resolution-limited maximum thickness of 15 µm (Chikawa, 1974).

Dislocations in a silicon crystal were observed with the PbO camera tube and a high-power X-ray generator (tube voltage: 60 kV, current: 0.5 A) under the conditions $\nu_p =$

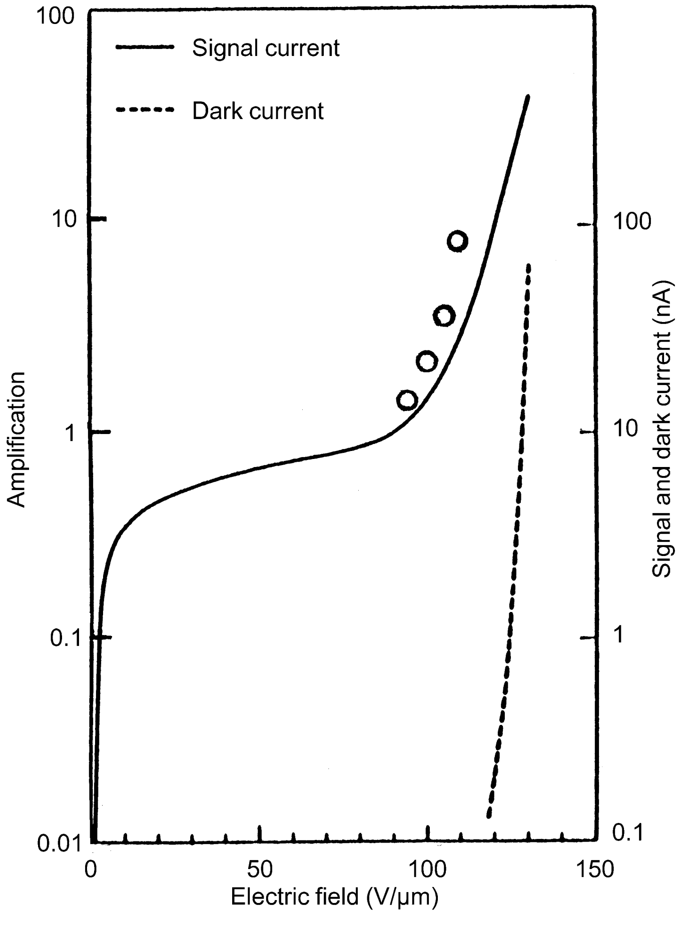

Fig. 7.1.7.3. Typical example showing dependence of the avalanche amplification on the electric field applied on the amorphous photoconductor (HARP). The solid and dashed lines show the amplification of signal current by visible light and dark current, respectively, for a 2 µm thick HARP layer. The right-hand scale shows the current (in nA). The open circles are the data for an 8 µm thick HARP layer by X-ray irradiation. Note that the thicker layer has higher amplifications owing to longer paths for running of holes.