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Comments on *Determination of X-ray flux using silicon pin diodes* by R. L. Owen *et al.* (2009). *J. Synchrotron Rad.* 16, 143–151

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The recent paper of Owen *et al.* (2009) describes the use of silicon photodiodes as detector standards in the X-ray range. The statement that commercially available high-quality silicon pin diodes are well suited for absolute flux measurements is certainly correct. However, several comments should be added.

(i) The approach to calibrate a silicon diode in the X-ray range by determining the relevant thickness from the angular dependence is called 'self calibration' and has already been applied at the Physikalisch-Technische Bundesanstalt (PTB) using the synchrotron radiation source BESSY (Krumrey & Tegeler, 1992). This approach was adopted and is still in use for photodiode calibration at the NSLS (Keister, 2007). Equation (5) in Owen *et al.* (2009) is similar to equations (3) and (4) in Krumrey & Tegeler (1992) but does not include diffusion effects. The procedure gives reasonable results but relies on data for the absorption coefficient with mostly unknown uncertainty.

(ii) In the photon energy range from about 5 keV to 20 keV, the absorption coefficient based on photoelectric cross-section data can be taken, for example, from the mentioned XCOM database (http://physics.nist.gov/PhysRefData/Xcom/Text/XCOM.html). However, Compton scattering is not taken into account, but contributes significantly at higher photon energies. The correct data for the entire energy range are the mass–energy absorption coefficients which can be taken from a different NIST database (http://physics.nist.gov/PhysRefData/XrayMassCoef).

(iii) A scintillation detector cannot be regarded as a primary standard detector to calibrate other detectors, especially not in the photon energy range below 10 keV. This is already obvious from the large error bars in Fig. 5 of Owen *et al.* (2009), which probably take into account the statistics only. The quantum detection efficiency of a scintillation detector does not have to be unity, and calibrating photodiodes in the pA range for use in the μA or even mA range is in fact not adequate. To be operated at low currents, photodiodes should have a shunt resistance of at least 500 MΩ (Keister, 2007); the value of 3.37 MΩ given in Owen *et al.* (2009) is thus extremely low. Furthermore, the shunt resistance varies drastically with temperature (about one order of magnitude for a temperature difference of 25 K), making a correction factor based on the shunt resistance very questionable.

(iv) For correctly calibrated and sufficiently large photodiodes, operated in the linear range with radiation of sufficient spectral purity, the photon flux measured with different photodiodes should be identical within a few percent. However, the fluxes presented in Table 2 of Owen *et al.* (2009) differ by up to 28% (*e.g.* at 5.8 keV and 8 keV). Thus at least one of the conditions mentioned above was not sufficiently fulfilled.

(v) For traceable flux measurements with low uncertainties, the direct calibration of the detector against a primary detector standard is the best approach. The highest accuracy is achieved with a cryogenic electrical substitution radiometer (Gerlach *et al.*, 2008). Photodiodes of all four types shown in Table 2 of Owen *et al.* (2009) have been calibrated this way; the results have been published (Krumrey *et al.*, 2007; Gerlach *et al.*, 2008). A calibration service with relative uncertainties below 1% is available at PTB in the spectral range from 0.05 keV to 60 keV.

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