Test Results on the Silicon Pixel Detector for the TTF-FEL Beam Trajectory Monitor

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Abstract

First tests of the silicon pixel detector for the beam trajectory monitor (BTM) at the Free Electron Laser (FEL) of the TESLA Test Facility (TTF) at DESY are presented. Measurements using 6 keV photons of the manganese K_α/K_β line allow to determine the electronic noise of detector and read-out and to calibrate the signal amplitude of different pixels. The sensitivity of the silicon detector to low energy X-rays down to 60 eV is shown. The accuracy of its position measurement is found to be better than 0.22 μm using a pulsed diode laser beam focused to a straight line

1. Introduction

In order to achieve the high brightness promised by the single-pass Free Electron Laser (FEL) [1] at the TESLA Test Facility (TTF), the electron beam position must be controlled to better than 10 μm over the 15 m long undulator.

With the beam trajectory monitor (BTM) [2] the off-axis spontaneous undulator radiation is detected through a set of pinholes by high resolution silicon pixel detectors. The sensitive area of the silicon pixel detector consists of two rows of each 12 active pixels as shown in Figure 1. To achieve the required resolution of the BTM the center of the photon spot has to be measured with a precision of 1 μm. The behaviour of the silicon pixel detector with respect to noise, quantum efficiency and spatial precision is presented.

Fig. 1. Anode structure of the silicon pixel detector; two pixel rows with a charge injection line across each row.

2. Calibration and Noise Determination

An absolute energy calibration of each detector pixel is obtained using 6 keV photons of the manganese K_α/K_β line from a ^{55}Fe source. The resulting calibration constants agree for neighbouring left and right pixels within 1%–4%. The Gaussian width of the pedestal peak is mainly caused by one source of noise, namely the leakage current. As expected we find that the noise grows proportional to the square root of the integration time and decreases by a factor of two when cooling the detector by 16 K. A noise charge (ENC) of about 50 e has been achieved at room temperature with an integration time of 20 μs.

3. Sensitivity to VUV Light

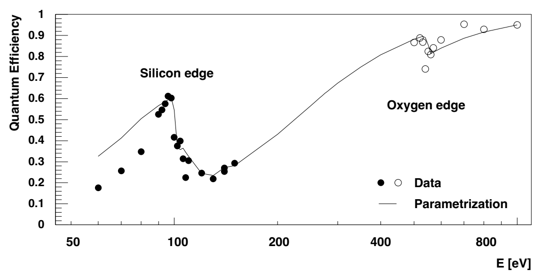

Fig. 2. Quantum efficiency for VUV radiation

The quantum efficiency of the silicon pixel detector was measured using a VUV beam at the synchrotron light source facility HASYLAB. It was illuminated with monochromatic light in the energy range of 50 to 1000 eV. The silicon detector response was normalized to the photo-electron emission of one of the focusing mirrors and the signal of a GaAs photodiode with known quantum efficiency as a reference. The observed reduction of quantum efficiency near the absorption edges (Fig. 2) can be explained by dead layers of 50 nm of silicon oxide and 30 nm of silicon, which have to be passed by the photons before they enter the sensitive region of the detector. For the energy region that will be used in TTF-FEL the quantum efficiency lies above 20%.

4. Position Resolution

The systematics of the position measurement of the pixel detector is studied by projecting a laser line-optic onto the pixel structure. The Gaussian width of the laser line (24 μm) is in the same range as the light spot that we expect in the TTF-FEL setup. Stepping the laser line (0.07 μm per step) across the two pixel rows allows to reconstruct the straightness of the laser line. For each pixel pair the relative difference between the signals of the left and right pixel, $\eta = (S_R - S_L)/(S_R + S_L)$, is calculated. For positions very close to the zero crossing one expects a linear dependence of η on the stepper position (Fig. 3). A periodic oscillation of 0.5 μm length is observed, which is caused by the inaccuracy of the stepping device. For every pixel pair the position of the zero crossing of η can be extracted from a fit of a straight line to the data points. Comparing these positions one gets agreement between the pixel pairs within a standard deviation of 0.22 μm.

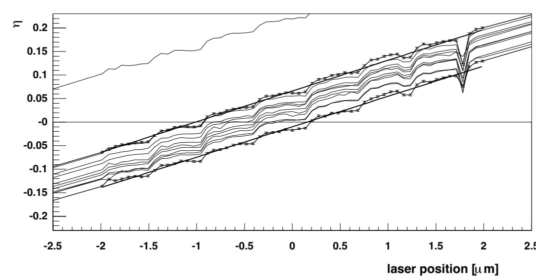

Fig. 3. Measurement of η versus the laser position

References

[1] TTF-FEL Conceptual Design Report, TESLA-FEL 95-03, DESY, June 1995;
J. Rossbach *et al.*, Nucl. Instrum. and Methods **A375** (1996) 269.

[2] J.S.T. Ng, TESLA-FEL 96-16, DESY, 1996;
AIP Conf. Proc. #413, eds R. Bonifacio and W. A. Barletta, 1997;
Proc. of the 8th European Symposium on Semiconductor Detectors 1998, to be published in Nucl. Instrum. and Methods A.