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A MONOLITHIC 7 CELL SILICON DRIFT DETECTOR MODULE FOR X-RAY SPECTROSCOPY

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Energy-dispersive semiconductor detectors find widespread application in the registration of fluorescence-yield X-ray absorption fine structure spectroscopy (fl-XAFS). Today mostly high purity Ge and Si(Li) diode detectors are used for this purpose. Silicon-Drift Detectors (SDD) were first introduced in 1984 [1]. They are based on high-resistivity n-type silicon. The bulk volume of the SDD is completely depleted by application of relatively small voltages - compared to standard diode detector - between p^+ contacts at the front and at the back side and a small n^+ anode in the centre of the detector cell. The electrical field in the SDD is shaped in a way that the generated charge carriers are drifting towards the small read out anode [2]. This design offers several advantageous properties:

- The small read out anode has a very small capacitance thus minimising rise time and noise.
- The SDD can be operated at or near room temperature.
- With a signal rise time of the order of 100 ns the SDD can work at very high count rates up to 1 MHz.

Based on a monolithic 7-cell SDD chip which was manufactured by PNsensors, Munich, Germany, we developed a complete SDD module including a specially developed read-out chip and housing. The complete module is shown in Fig. 1. The read out chip was designed to reach count rates of several 100 kHz and a spectral resolution of 250 - 600 eV (FWHM Mn-K_α), depending on the count rate. The SDD chip has 7 hexagonally shaped cells with integrated JFET in the centre of each cell. The JFET is the first transistor of the signal amplification chain. The read-out ASIC is located behind a radiation protection shield. The housing for the SDD and read-out chip is completely made from pure AlN. The hexagonal rod behind the detector head is made from Cu which provides very good thermal conductivity for the heat transport form the hot side of a Peltier element which is used to cool the read-out ASIC and the SDD down to temperatures between 0° and 10°C.

Spatially resolved test measurements like line scans with a 4×4 μm² pencil beam had shown that the signal-to-noise ratio (S/N) can be improved by a factor of ~10 by covering the cell borders and the JFET in the centre of each cell with a mask. The reason for this effect is that

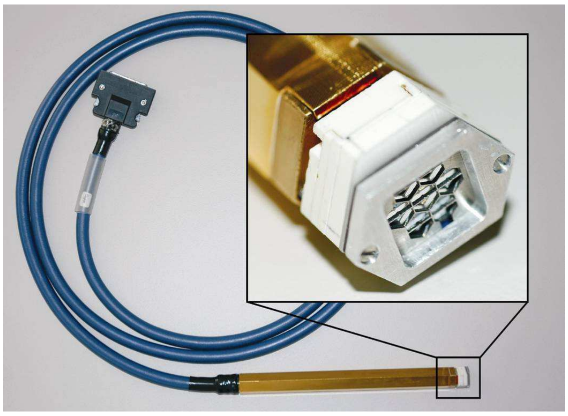

Figure 1. Photograph of a complete detector module, the inset shows the head of the detector with the AlN housing (white) and a Zr mask in front of the SDD chip.

the charge which is produced by photons which are absorbed in these regions is split between neighbouring cells or partly lost. We have chosen Zr metal as material for the mask, because the window between the L and K emission lines corresponds well with the foreseen operation range of the detector modules.

Without light tight entrance windows in front of the SDD chip these modules are used in the vacuum and under strict exclusion of any visible light. Operation in vacuum allows working at very small distances from the sample and thus achieving a high coverage of the total solid angle with a small detector. Meanwhile the first modules were used for test experiments and during a number of user experiments at HASYLAB XAFS beamlines.

The influence of the mask on the S/N ratio is visualised in Fig. 2. It shows fluorescence spectra of a gold foil (Goodfellow, Germany) exited at 12 keV. The beam spot on the foil has a size of 10×1 mm². It is clearly visible that with increasing distance between sample and SDD the escape peak becomes better visible due to the increased S/N ratio. The mask is working more effective if the distance becomes larger, because the number of photons which pass under the mask from the side decreases.

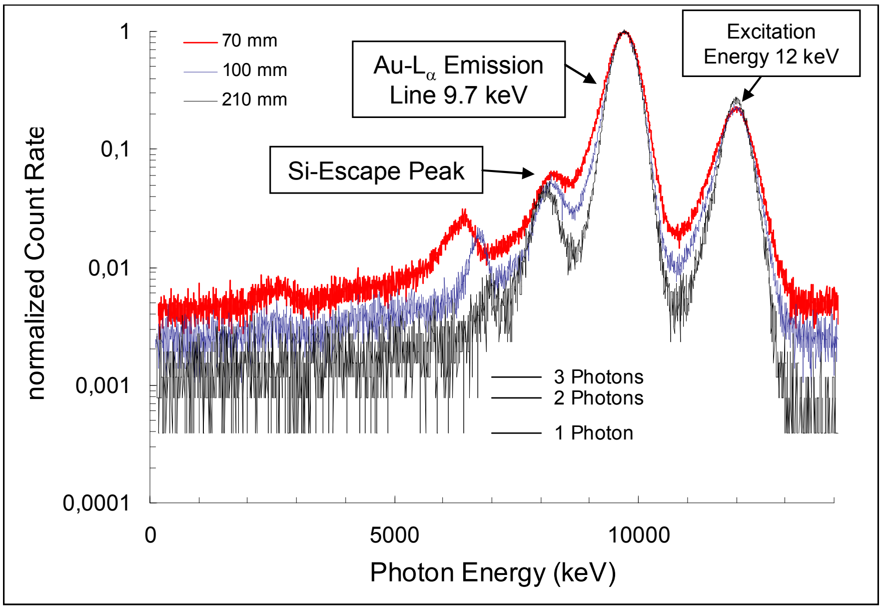

Figure 2. Au-L fluorescence spectra measured at differing distances between detector and sample.

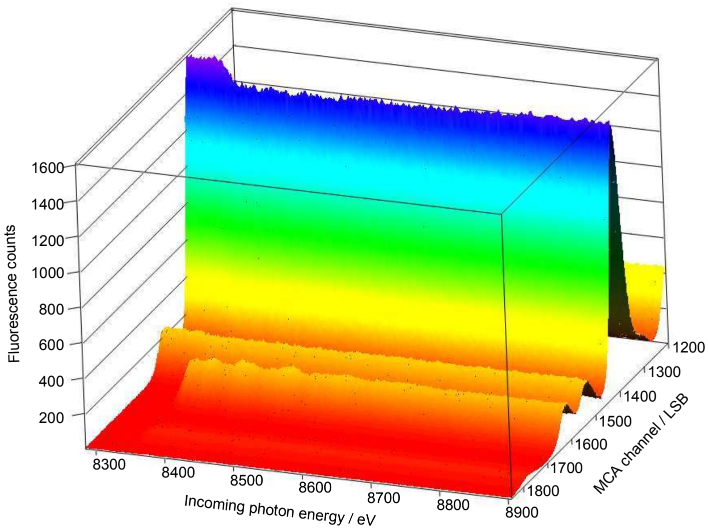

Figure 3. Fluorescence spectra registered during an EXAFS scan over the Ni-K edge of a stainless steel sample.

Figure 3 shows a pseudo 3-d plot of a Ni-K edge EXAFS scan of a stainless steel foil (Cr17FeNi11, Goodfellow, Germany). The Ni-K_α emission line with the edge and the first XAFS oscillations is visible in the front of the graph. The extracted EXAFS spectrum is shown in figure 4 together with the simultaneously registered transmission EXAFS spectrum. Samples like this stainless steel foil which produce a large number of mostly background photons are a typical application for a detector which enables very large count rates per mm^2 active area.

The quality of the EXAFS signal is only limited by photon-counting statistic. This was shown in test scans without changes of the incoming photon energy. The standard deviation of the count rates within the pre-set energy window was always equal to the square radix of the average count rate.

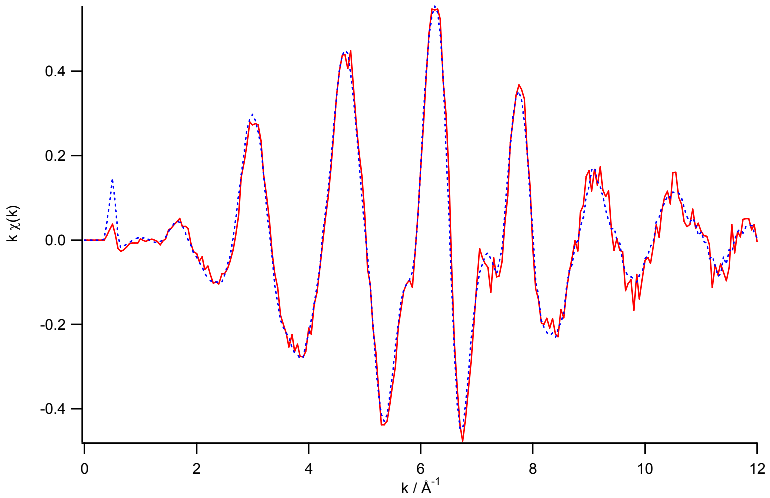

Figure 4. Ni-K edge EXAFS spectra measured on a stainless steel foil in transmission (blue) and SDD-detected fluorescence (red) mode XAFS.

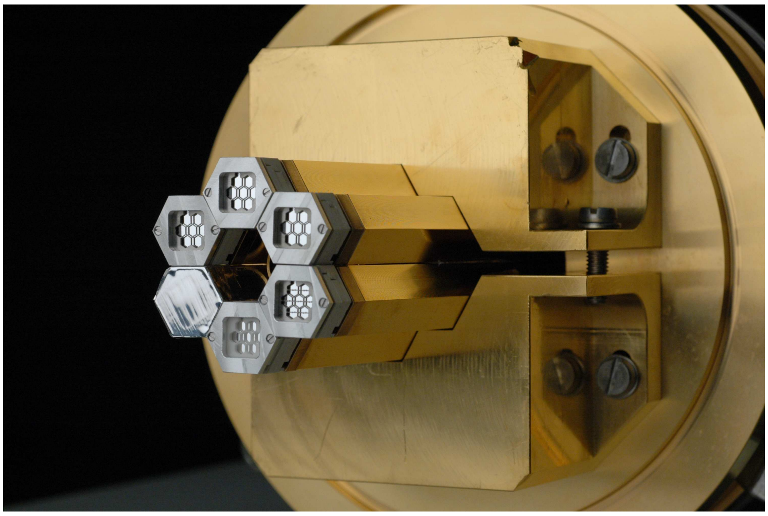

Figure 5. Holder for up to 7 detector modules.

Outlook

Figure 5 shows a special holder for up to 7 modules. With the help of this holder it is possible to work with a 49-cell detector system which is able to achieve count rates of several MHz with an energy resolution around 300 eV (FWHM Mn-K_α). Obviously with a bundle of seven of our presently available detector module there is a lot of insensitive area between the detectors. It would however be very easy to use the read-out ASIC together with different - larger - SDD sensor arrays.

References

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