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CUBE: The SDD Preamplifier For Excellent Energy-Resolution and High Count-Rate Performance

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The continuous advancement in radiation sources and X-Ray optics enables the delivery of higher and higher photon fluxes with respect to what was possible in the recent past. Moreover, most of the applications nowadays require spectroscopy-grade detectors and electronics to separate as many X-ray fluorescence lines as possible. Consequently, detector-system requirements are steadily moving towards higher count-rate and better spectroscopy capability.

Recently, XGLab proposed a novel CMOS preamplifier, named CUBE [1], capable of reading-out very low capacitance devices, such as Silicon Drift Detectors (SDDs). The CUBE preamplifier is a small, low-power monolithic unit which can be placed close to the SDD (Fig. 1). It delivers a high signal level at the output of the module. There is no sensitive loop outside the module ensuring excellent peak stability. Using CUBE it is easy to drive signals a "long" distance between the detector front end and outside electronics. The very low serial noise guarantees high count rate capability and excellent energy resolution thank to the use of ultra-short peaking times. The peaking time is a measure of the time required by the electronics to process single X-ray photons: the shorter the peaking time, the higher the achievable counting rate. All these characteristics together provide practical advantages in many applications such as X-ray fluorescence analysis, X-ray diffraction and EDS for electron microscopy (SEM and TEM) offering the possibility of high count rate spectroscopy while preserving the energy resolution required to identify neighboring or overlapping peaks, which is particularly challenging at low energies.

For experimental characterization, the CUBE preamplifier has been connected to commercially available SDDs and used in X-ray spectroscopy measurements at different peaking times. Figure 2 shows the energy resolution at 5,9 keV, FWHM of the Mn K alpha peak versus peaking time, measured with a small area SDD connected to the CUBE preamplifier and cooled at -50°C. A resolution better than 160 eV FWHM at the ultra-short peaking time of 32ns was achieved. Such a short peaking time enables measurements up to several millions of counts per second ICR. At longer peaking times the resolution is 123 eV FWHM at Mn K alpha and thus suitable for challenging EDS applications, as mentioned above.

Figure 3 shows a comparison of the typical measurement data, obtainable with a CUBE device, and a commercial preamplifier based on a JFET front-end transistor. In all the cases, the detector used was a 25 mm^2 SDD. The measurement has been carried out at the ELETTRA synchrotron irradiating a thin sample composed of a deposition of Zinc with a trace of Gallium. At 1µs peaking time and low input count-rate the two preamplifiers show a comparable performance, with Cube delivering the better energy resolution. The Mn-Kα energy resolution with the CUBE and the JFET is 132 eV and 152 eV FWHM respectively. The increase of the input count-rate up to 800 kcps (see Figure 3, on the right) imposes the use of a much shorter peaking time to keep the dead-time of the measurement to an acceptable level. In that condition, the difference in the performance of the two preamplifiers is evident. While with the JFET it is practically impossible to have satisfactory spectroscopy performances, CUBE still offers the superior energy resolution of 138 eV FWHM. Moreover, the use of short peaking times reduces the impact of the detector leakage current on the total electronic noise. Thus, CUBE allows to operate the detectors also at room temperature (or slightly cooled). This introduces practical advantages in many industrial applications: Avoiding the need of high-power cooler system, enabling smaller heat-sinks and reducing the effect of system start-up and temperature stabilization can be helpful e.g. for optimizing portable and hand-held instrumentation and multiple, large area and annular detector arrangements close to the electron microscope pole piece for achieving a high X-ray collection angle.

References:

[1] L. Bombelli *et. al*, NSS Conference Record (2012)
[2] R. Alberti *et. al*, X-Ray Spectrometry (2017)

Figure 1. Placement of CUBE in a detector module which provides encapsulation and cooling

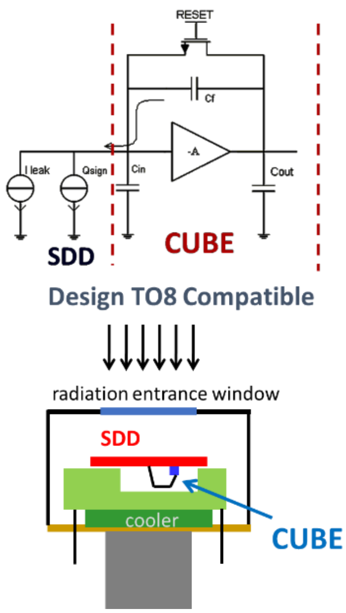
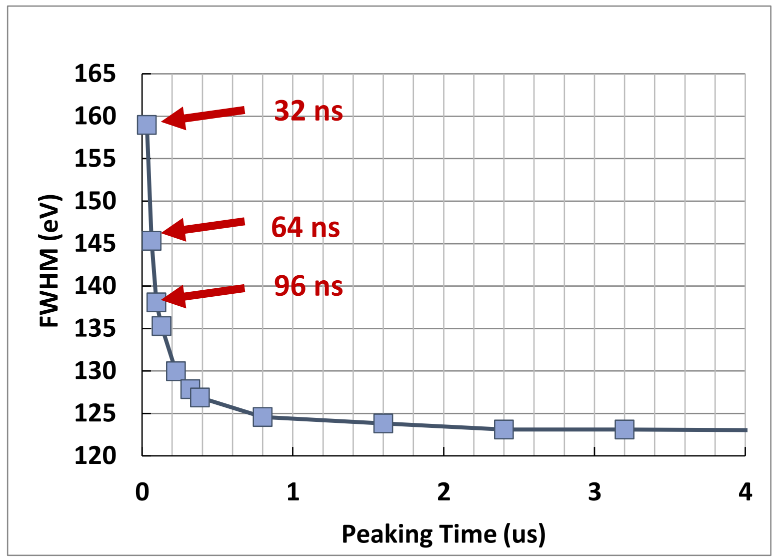


Figure 2. Energy resolution at the Mn-Ka line ^{55}Fe calibration source measured with an SDD, at a temperature of -50° C.



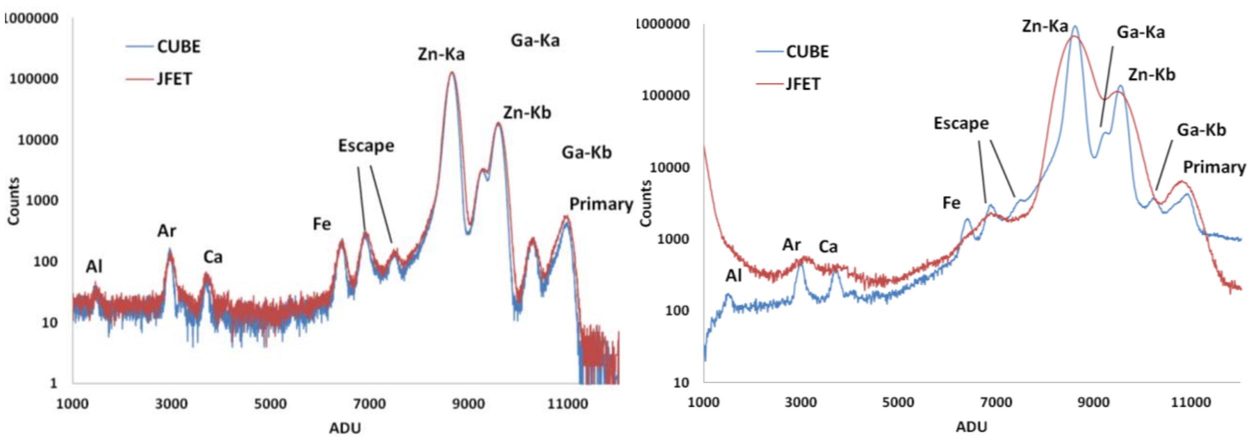


Figure 3. (Left) spectra measured with 1µs peaking time using the ELETTRA synchrotron radiation of 11keV, 100 kcps of input count-rate, 27% dead-time. (Right) Measured spectra with 0.3 µs peaking time, 800 kcps of input count rate, 54% dead-time.

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