X-Ray Spectroscopy with a CCD Detector

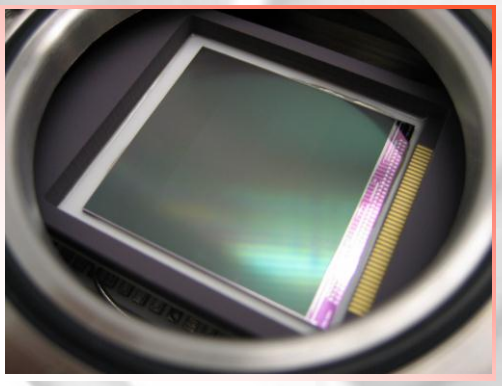
Application Note

In addition to providing X-ray imaging solutions, including CCD-based cameras that image X-rays using either direct detection (0.5-20 keV) or indirectly using a scintillation layer (5-500 keV), Xcam also offer a number of camera systems developed for X-ray spectroscopy applications. The CCD is an ideal detector for use in both dispersed and photon counting X-ray spectroscopy applications, and its ability to obtain both spectral and spatial information simultaneously allows it to be used for 'multi-spectral imaging'. Swept Charge Devices (SCDs) are also available for X-ray spectroscopy applications where spatial information is not required and can provide good spectral resolution using relatively large area devices (up to 400 mm^2).

Imaging X-ray Spectroscopy with a CCD

Cameras developed by Xcam can provide low noise systems of <5 electrons r.m.s., equivalent to ~140 eV at Mn-K (5898 eV), for spectroscopy applications. Some of the benefits of the available Xcam CCD camera systems for X-ray spectroscopy are:

- High performance cryogen free system
- Large collecting area - for low photon yield applications
- Suitable for portable applications
- Energy resolution comparable to Si(Li) detectors
- High peak to background ratio in the spectrum
- Spatial information is retained
- Full performance using thermoelectric cooling

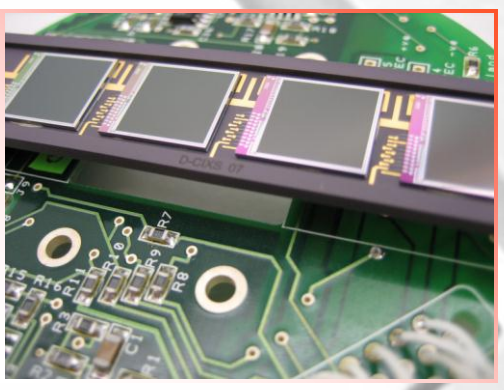


An Xcam CCD camera head, suitable for X-ray imaging and spectroscopy applications

Non-imaging X-ray Spectroscopy with a CCD

Swept Charge Devices (SCDs), such as e2v technologies CCD54 and CIXS devices, offer a low cost, large area, fast read-out alternative to the CCD, for situations where spatial information is not required. These devices are designed to operate at temperatures that can be achieved using Peltier cooling, making them a good replacement for the Si(Li), PIN and SDD devices. Some of the features of SCDs include:

- Low cost
- Efficient detection over the 0.5-10 keV band
- Large area, up to 400 mm^2
- Typically ~5 electrons r.m.s. noise, giving 80 eV FWHM at 1 keV and 130 eV FWHM at 6 keV
- Peak to background ratio of 4000:1 with collimation
- Suitable replacement for Si(Li), PIN and SDD devices
- Can be operated warm requiring no liquid Nitrogen for cooling
- Fast read-out

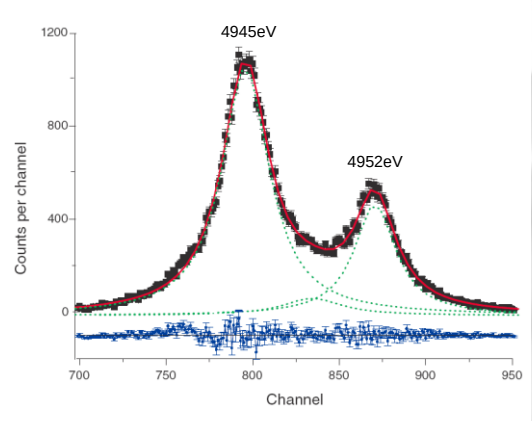


A CIXS device featuring four CCD54 detectors in one ceramic package

Dispersed X-ray Spectroscopy

In dispersed X-ray spectroscopy (using for example a grating or crystal), the CCD chip is used for detection of the dispersed spectrum, where the energy is determined from the positional information. Some of the camera specifications offered by Xcam for spectroscopy systems are:

- Direct detection of X-rays
- Cryogen-free thermoelectric cooling, with supplementary air or water-cooling
- A selection of entrance windows are available for optimal transmission at the energy range of interest
- Possibility of direct coupling to a vacuum system or installation of the sensor in the user's chamber
- 14 bit or 16 bit digitisation
- Typically <5 electrons r.m.s. noise
- Full software control of the system including, readout parameters, binning and windowing modes

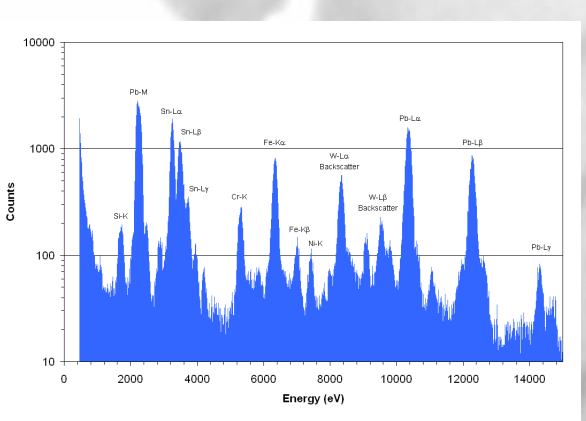


A dispersed V Kα spectrum obtained by inserting a wire probe near the electron beam of an EBIT. The spectrum is fitted by a sum of three Lorentzians with the residuals also shown (image used courtesy of Joshua Silver)

Photon Counting Spectroscopy

The low noise of CCDs and high stopping power over the 0.5-10 keV range, makes them the ideal photon counting detector for X-ray spectroscopy applications, such as X-ray Fluorescence (XRF). Key features of photon-counting X-ray spectroscopy systems available from Xcam are:

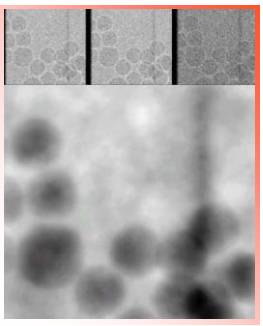
- Cryogen-free operation using a thermoelectric cooler
- Typical Operating Temperature of -35°C, depending on user requirement
- Resolution of ~140 eV at Mn-K (5898 eV)
- Active area of 1-6 cm^2 dependant on CCD type (ideal for low photon flux applications)
- Count rate 20000/s
- High detection efficiency over 0.5-10 keV band
- Full software control of your system including, readout parameters, binning and windowing modes



An example of fluorescence from PbSn solder spectrum obtained using an SCD

Multi-spectral Imaging – Combining X-ray Spectroscopy with Imaging

At the same time as a spectrum is being recorded, the CCD can also record an image from the sample; this technique can be used in both X-ray Diffraction (XRD) and projection microscopy applications. Further information about using Xcam hardware for X-ray projection microscopy can be found in the Xcam application note: 'X-Ray Projection Microscopy with a CCD Detector', available from Xcam, or by download from the Xcam website.



Images of 9 μm latex spheres acquired simultaneously using multi-spectral imaging at 3.3, 1.7 and 5.0 keV

A more detailed version of this application note can be downloaded from the Xcam website, http://www.xcam.co.uk/notes/index.html

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