RIXSCam™ – A HIGH PERFORMANCE PHOTON-COUNTING CAMERA TO IMPROVE THE RESOLUTION OF RIXS EXPERIMENTS

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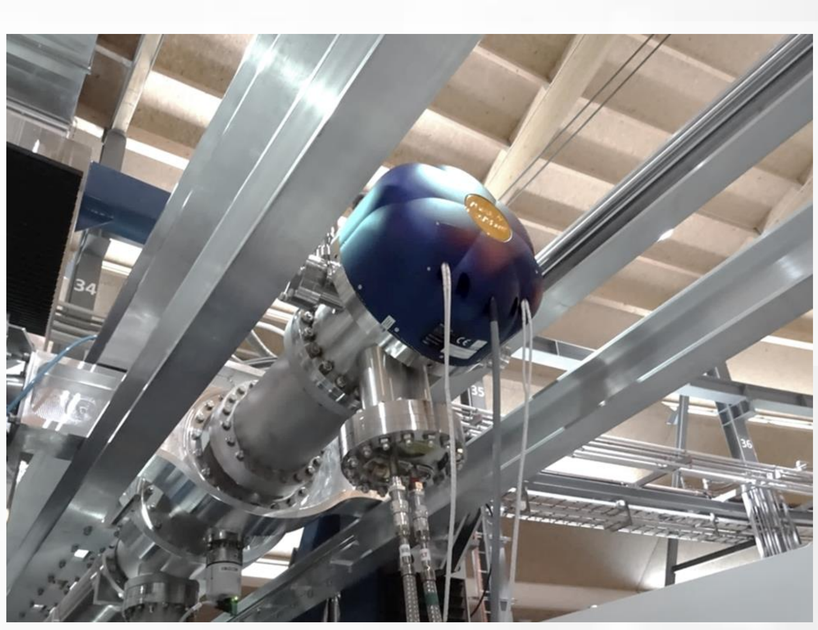
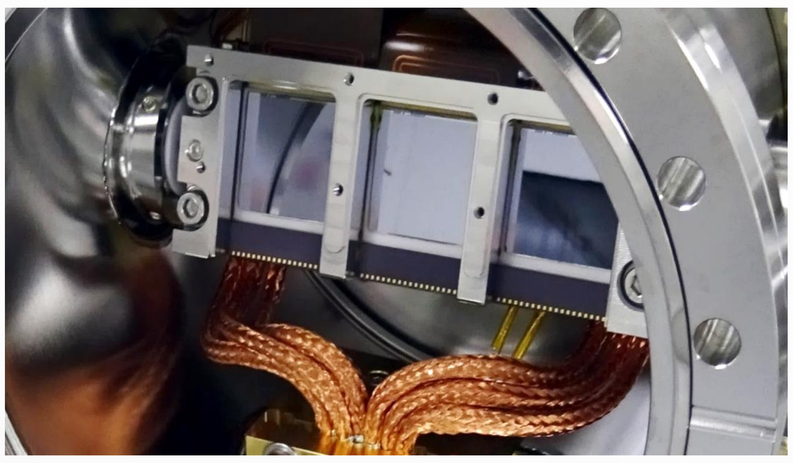
Introduction

RIXSCam is an advanced system developed by XCAM for synchrotron radiation facilities in collaboration with the Paul Scherrer Institute (PSI) and the Open University in the UK. Resonant inelastic X-ray scattering (RIXS) is a photon-in photon-out spectroscopy technique which probes the structure of matter by exciting resonances in the material to be studied. The ultimate energy resolution comes from a combination of the beam properties, the spectrometer and the detection system. The RIXSCam produces an improvement in resolution from ~25 μm with standard integrating CCD cameras, down to ~2 μm when using the EMCCDs at high gain in "photon counting mode" in combination with centroiding algorithms.



RIXSCam camera head installed at the ADRESS beamline at PSI

The EMCCD Focal Plane



Three EMCCD detectors on a rotatable cold bench

The detectors used in the RIXSCam are large area, back-illuminated Electron Multiplying CCDs (EMCCDs). They can be operated in normal integrating mode, the same as a conventional CCD. They also have a high gain mode where the signal is amplified in the readout register through an avalanche gain process. This has the effect of reducing the readout noise to less than 1 electron rms

High gain and low readout noise means single soft X-ray photons in the energy range 250 – 3000 eV can be detected and the interaction position centroided to an accuracy of ~2 μm rms.

Features of the RIXSCam

A choice of 2 or 3 EMCCDs can be used in the RIXSCam for increased detection area and hence throughput. This has the effect of increasing the throughput of RIXS beamlines by a factor of 2 or 3 respectively as previous cameras using 1 detector.

One of the main sources of noise in CCDs is the dark current. In order to detect single soft X-ray photons the dark current has to be suppressed. The EMCCDs sit on a cold bench. This is cooled using copper braids which are attached to a cold finger and is cooled using a Cryocooler. The operating temperature range is -110°C to -50°C.

The EMCCDs are placed on a rotatable bench with a 20° - 90° variable detector angle. This allows the user to control the effective pixel size through area projected to the beam. Rotating the detectors will also change the quantum efficiency (QE) due to changing the depth of the detector which must be traded against the resolution gain.

Centroiding algorithms have been developed that further improve the spatial resolution of the EMCCDs to much better than the pixel size.

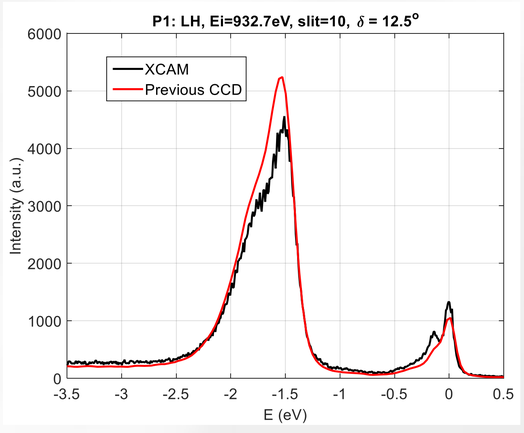
	Previous CCD at PSI	Photon counting with centroiding
Resolution	25 µm	Sub-pixel, as low as 2-3 µm
Readout time	42 s (100 kHz) or 4.2 s (1 MHz)	1 s (3 MHz)
Readout noise	3.48 (100 kHz) electron rms 10.8 (1 MHz) electron rms	< 1 electron rms

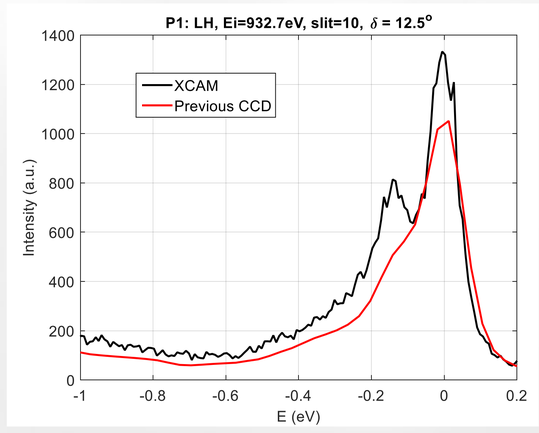
Results from PSI

The use of 3 detectors have tripled the total throughput of the previously installed CCD camera at the RIXS beamline at PSI. Due to the centroiding algorithms, the energy resolution has also improved by 30%.

The improved resolution of the RIXSCam means that previously unresolved excitations can now be resolved due to the sub-pixel resolution.

A comparison of results from the previous CCD and the RIXSCam are shown below. Here the magnon excitations that were not resolved by the previous CCD can clearly be seen using the RIXSCam.





Single Detector RIXSCam

The 2-3 sensor RIXSCam is a high performance camera system achieving both high throughput (from the use of multiple CCDs) and high resolution. For applications which do not need the high throughput created by the 3 detectors, a new single detector RIXSCam has been developed which can produce the same spatial resolution performance as the main RIXSCam, at a lower cost.

The single detector is mounted on a 6" CF flange at a fixed gamma-angle and uses Peltier cooling in order to keep cost to a minimum, operating at -70°C. This new camera type is currently in development and results will be available shortly.

Resolution Test Equipment

New equipment has been designed and built at XCAM to test the resolution performance of the RIXSCam. The equipment includes a new vacuum chamber with an X-ray tube attached. The X-rays generated will be fired at a target wheel with targets of various materials attached to give a choice of resulting scattered X-ray energy from 300-6000 eV.

A knife-edge will then be placed near the CCD surface to project a light/dark transition on the detector. The resolution of the CCD will then be determined from the contrast of the edge. Using this technique, the resolution performance of the camera can be measured during the testing at the factory.

This will also enable different avenues of research to be pursued, such as the performance of the centroiding algorithms as a function of CCD angle.