



# Case Study: Custom CCD for Japanese X-ray Free Electron Laser Experiment

## Introduction

XCAM was asked by **Dr Takaki Hatsui, Team Leader, Data Acquisition Team XFEL Project** to assist with establishing if a custom CCD detector might be suitable for capturing the diffraction patterns that would be produced by the Japanese XFEL experiments when operation begins in 2010. A suitable detector would require the following characteristics:

- Each pixel to hold 1000 12 keV X-rays, equivalent to a pixel well capacity of at least 3M electrons (most scientific CCDs have full well capacities <500k electrons)
- Large area to capture the full extent of the diffraction pattern
- Frame rates of 60Hz for best use of this expensive facility (most large area CCDs only operate at ~1 Hz)
- X-ray radiation damage needs to permit operation for at least 1 year before replacement
- Detection of both single X-ray photons and beams of extremely high intensity needs to be possible with a single device
- The energy of the beam would be 6-12 keV

XCAM came up with a CCD concept which encompassed all of the above in a single detector, specified an initial value for each technical specification and investigated particular issues that required further study.

## Radiation Damage

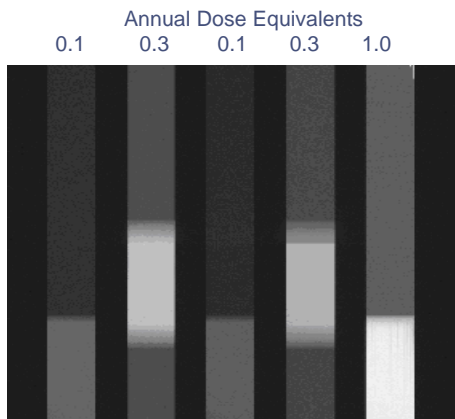


Fig 1: Leakage Pattern in Irradiated CCD47 used for Radiation Damage Study

: CCDs were not designed to operate with such high X-ray doses which amounted to in excess of 50 Mrad/yr close to the beam axis; XCAM conducted a radiation damage study which involved irradiating devices so that they received incremental doses which were representative of the dose that the device might be expected to experience during a year's use in the experiment, and characterising them to examine the damage. The results confirmed that, with careful choice of CCD manufacturing processes, devices could be produced which would operate for a minimum of a year before requiring replacement.

## Spatial Resolution under the Intense X-ray Pulse

One of the key concerns with silicon imaging technology was related to the generation of a sudden huge signal in the pixels, which was significantly greater than the device doping concentrations, and which would subsequently destroy the electric fields within the device, creating a very poor spatial resolution, in which the intense diffraction peaks were essentially "blurred". As a result of the work it was possible to demonstrate that for the MOS CCDs manufactured by e2v technologies, there would be no appreciable degradation in the point spread function (PSF) arising from the intense signal generated in a few ns.



Fig 2: (Left) The CCD38 used for evaluation of high signal handling capacity CCDs, and (right) the CCD30-11 used for radiation damage studies

## High Full Well Capacity

CCDs traditionally have been used in very low signal applications and part of the study involved would conducting tests to ensuring that the pixels of the custom sensor could have a high full well capacity.

## Custom Sensor Specification

The various work packages, once completed, enabled XCAM to produce a specification for a custom sensor, for which a contract was awarded to e2v technologies in March 2009.

*"Owing to the outstanding and unrivalled ability of XCAM Ltd, we successfully launched the development project of a novel CCD detector dedicated to our XFEL on March 18th, 2009. We all thank XCAM Ltd for their crucial and enthusiastic contributions."*

**March 20th, 2009**  
**Dr Takaki Hatsui,**  
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**XFEL Project Head Office, RIKEN**  
**March 20th, 2009**